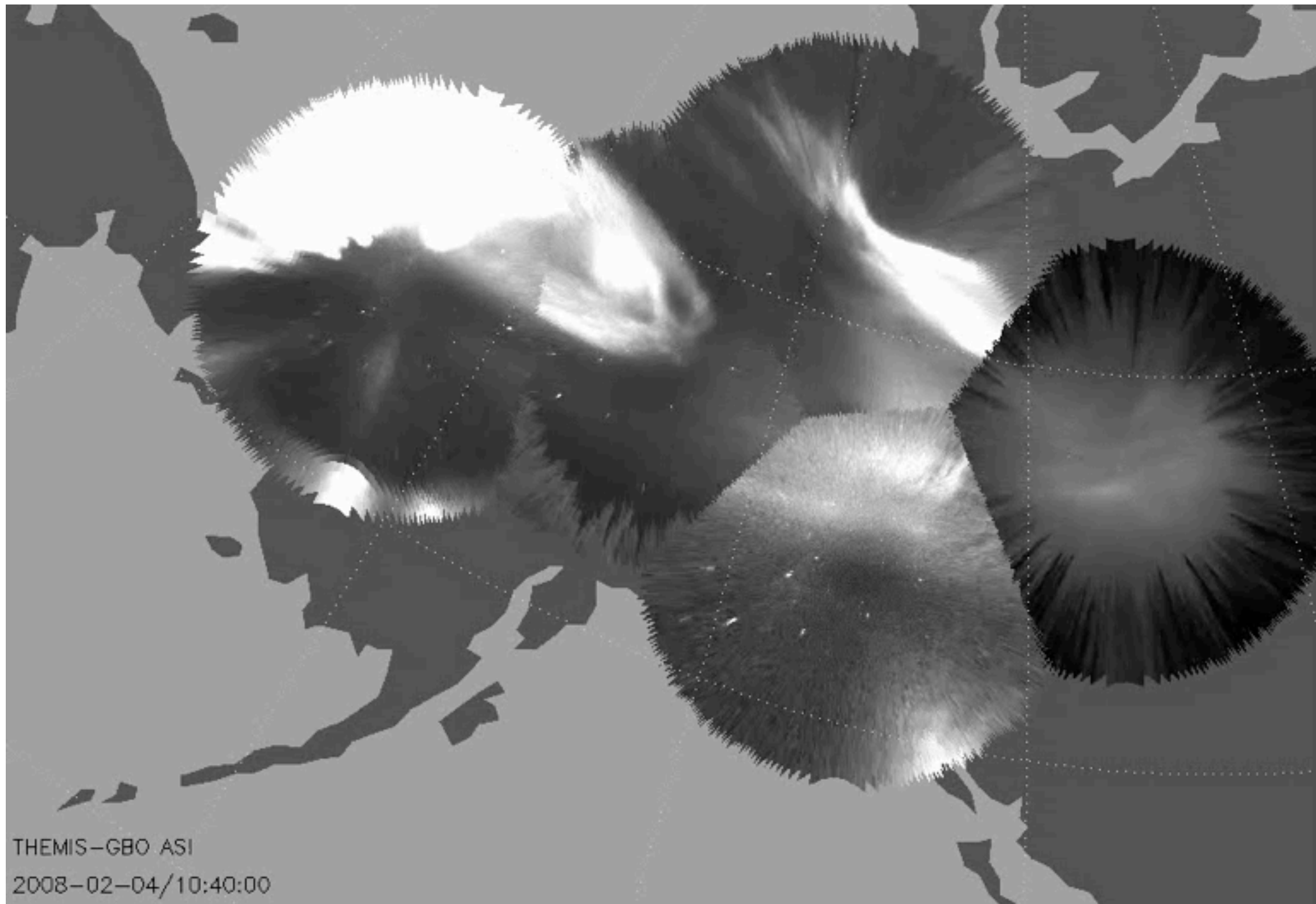


Substorm initiation and dynamics

Larry Kepko

NASA Goddard Space Flight Center



Traditional NENL

Expansion

Distant X-line

NENL

Dipolarization

Flow

Transition region

Earth

Pi2 & SCW

Equatorward
boundary

Nothing?

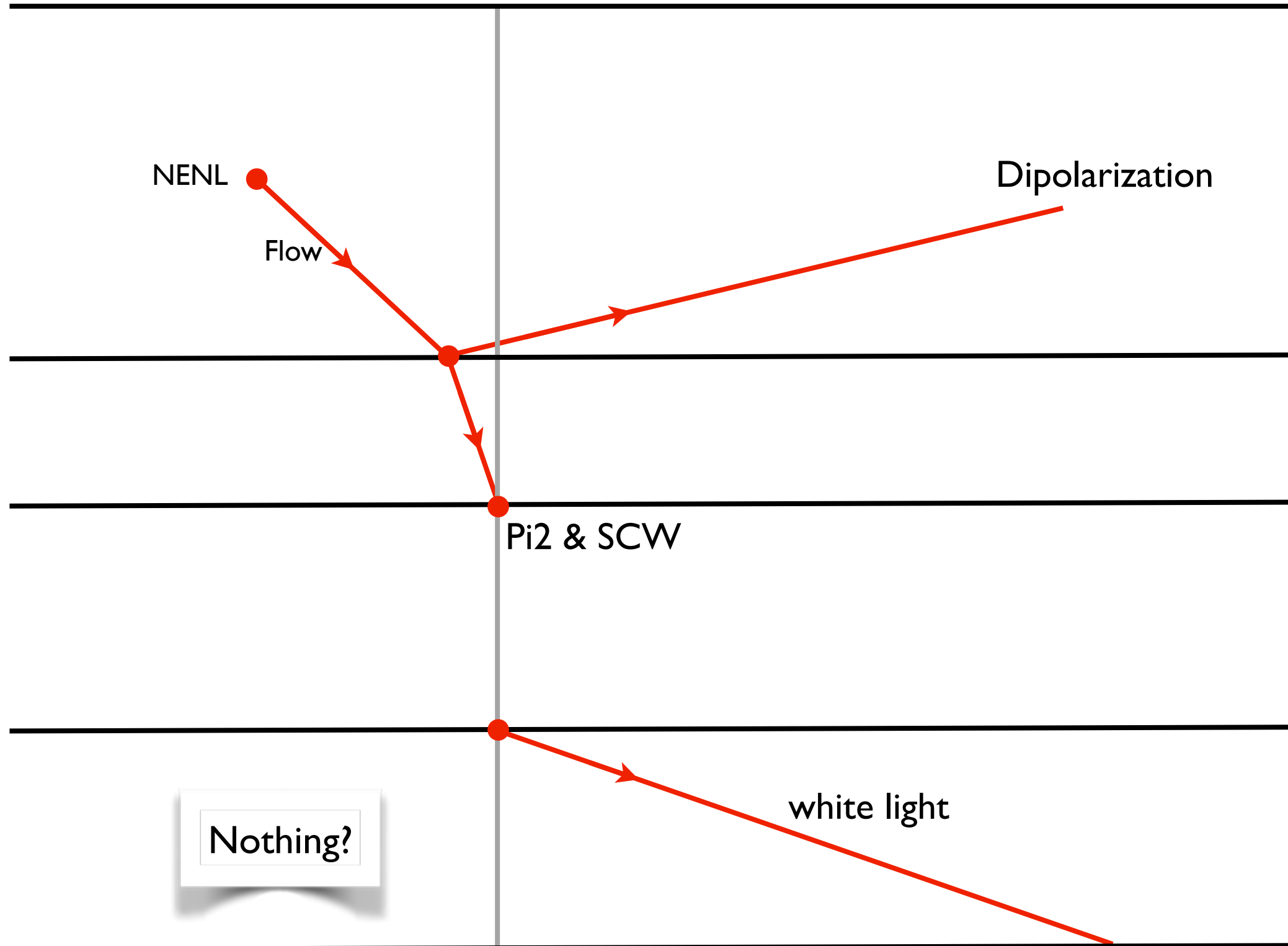
white light

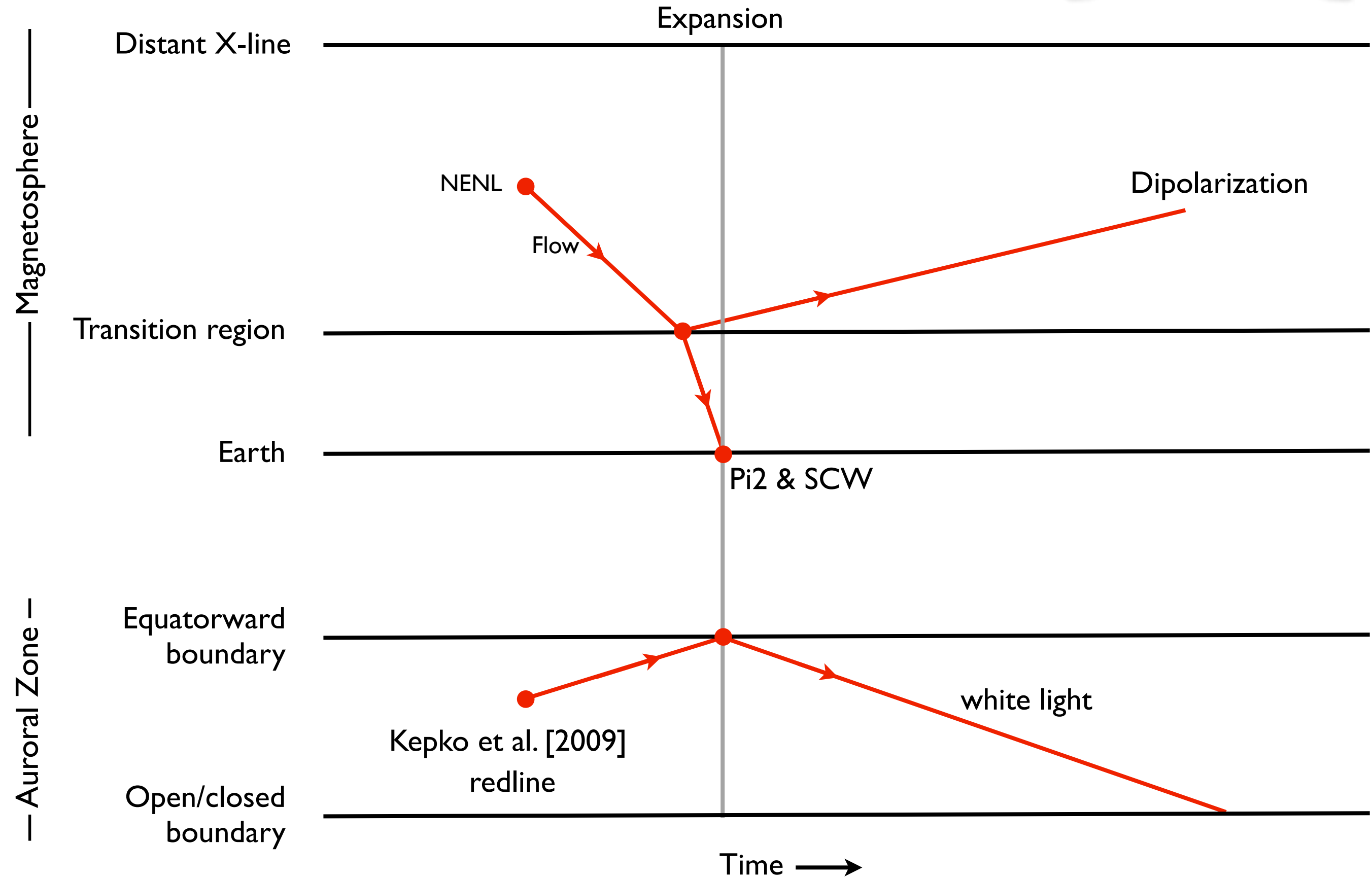
Open/closed
boundary

Time →

— Magnetosphere —

— Auroral Zone —





Current Disruption (CD)

Expansion

Distant X-line

(further)
dipolarization

NENL

Flow

NENL

Flow

Rarefaction

Transition region

Instability growth

Earth

Pi2 & SCW

Equatorward
boundary

6300

white light

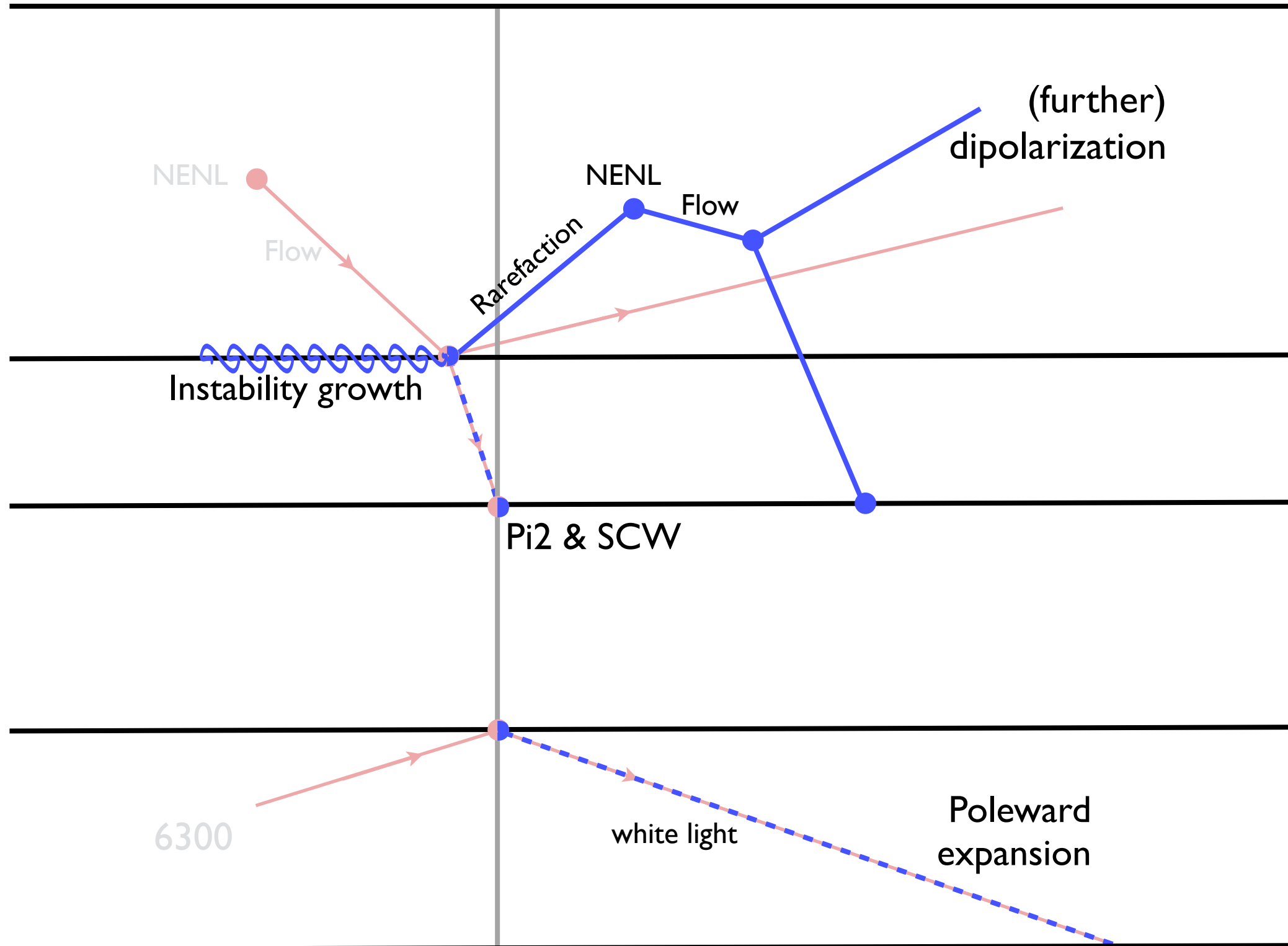
Poleward
expansion

Open/closed
boundary

Time →

— Magnetosphere —

— Auroral Zone —



Expansion

Distant X-line

“trigger”
flow

Transition region

Earth

???

Pi2 & SCW

NENL

Flow

(further)
dipolarization

Rarefaction

Instability growth

Equatorward
boundary

Azimuthal motion

“trigger”
streamer

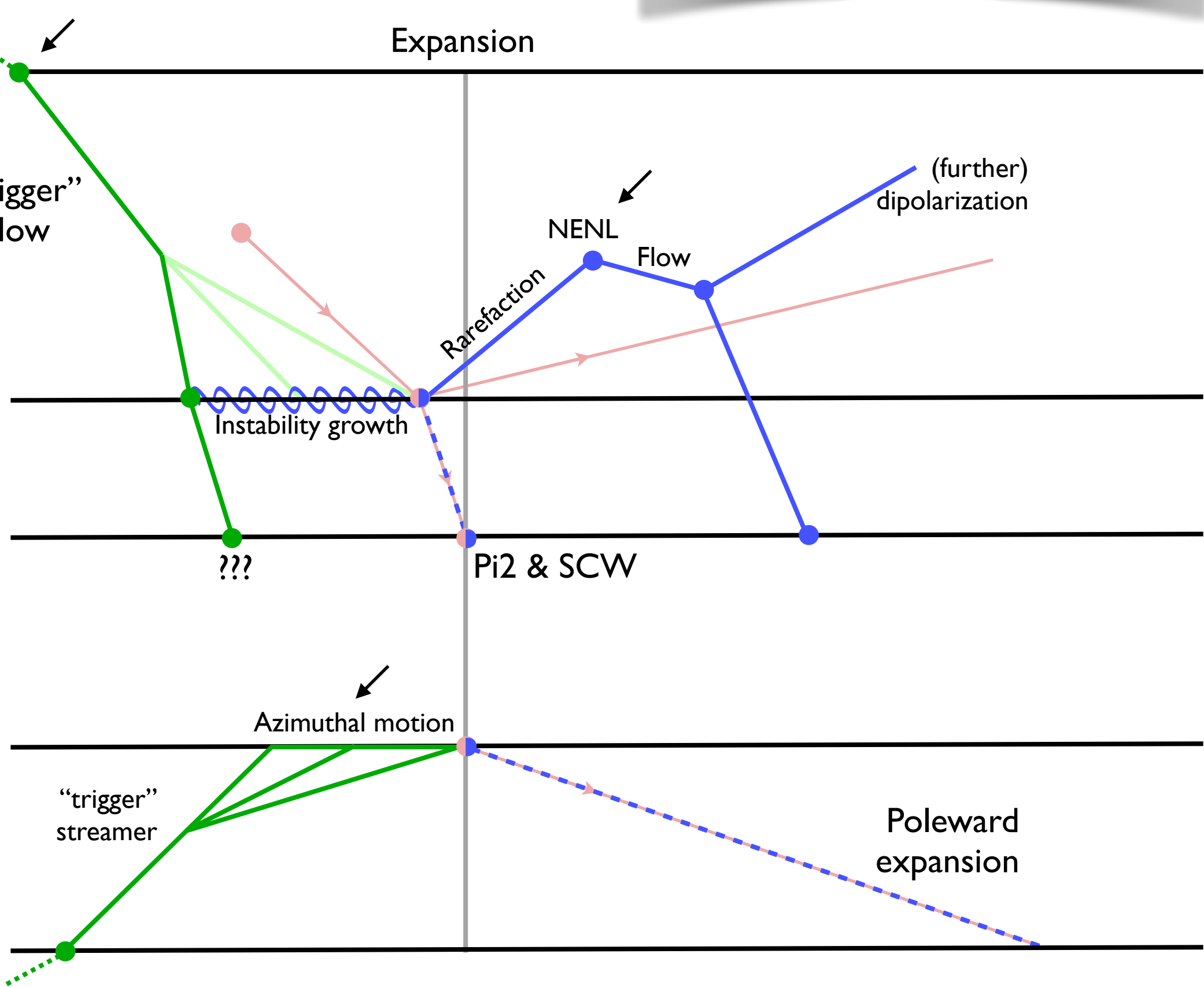
Open/closed
boundary

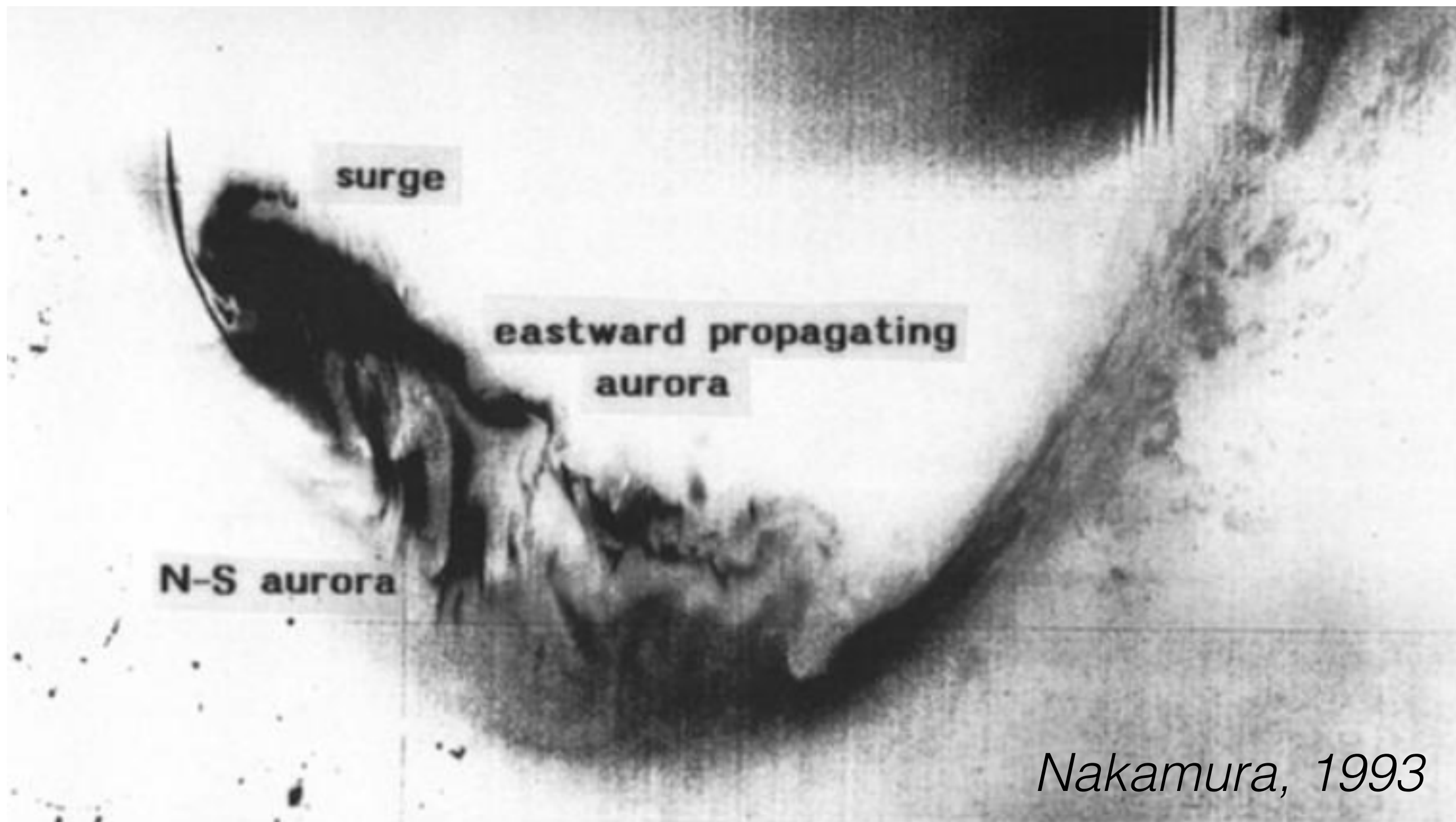
Poleward
expansion

Time →

— Magnetosphere —

— Auroral Zone —

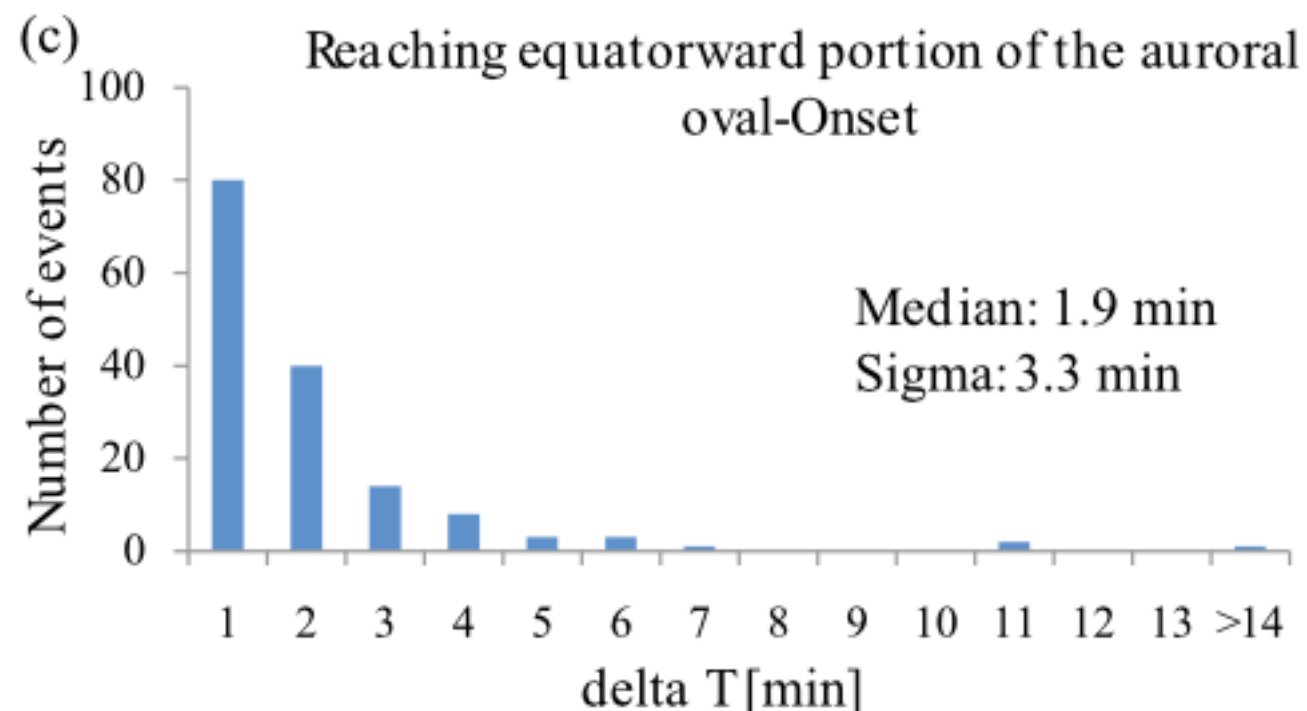




Known for decades NS aurora occur eastward of surge, lead to intensifications & equatorward boundary activity. The new claim is that NS streamers lead to **substorms**

Key Questions and Issues

1. NLS assumes ionosphere represent a screen to magnetospheric convective motion – specifically, “streamer” = flow bursts
2. What does it mean when an arc brightens?
3. NLS conflates substorms & intensifications (important) ←
4. How often are streamers observed to initiate substorms? Claim is 95%
5. What is the *time delay* and *local time* between streamer contact and expansion?
 - If $dt/MLT=0$, consistent with flow burst model
6. Analysis is highly subjective and not reproducible (not their fault)



More recent work involves polar cap patches and separating onset from onset signatures. Not discussed here (mostly)

Four types of substorm events

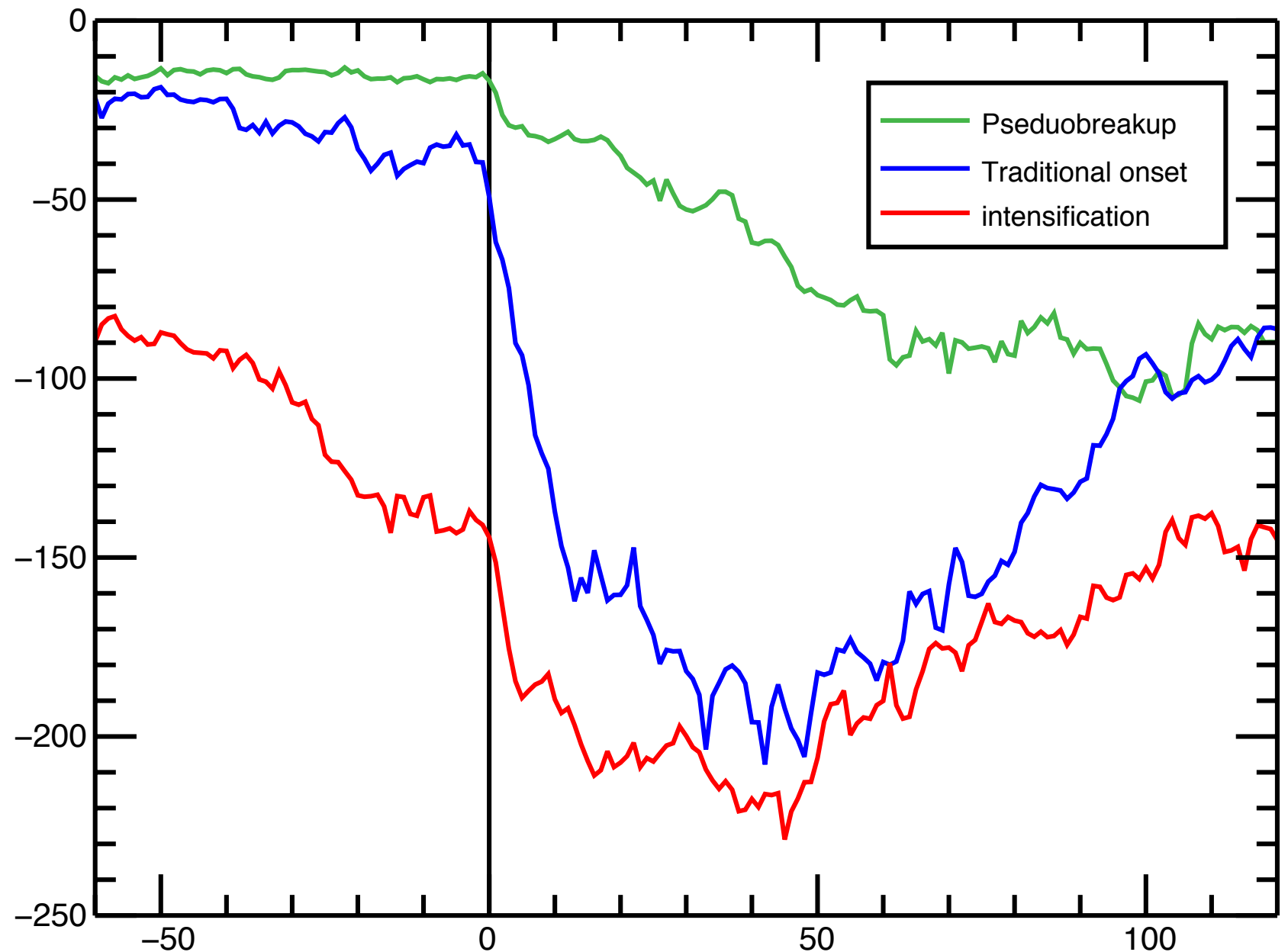
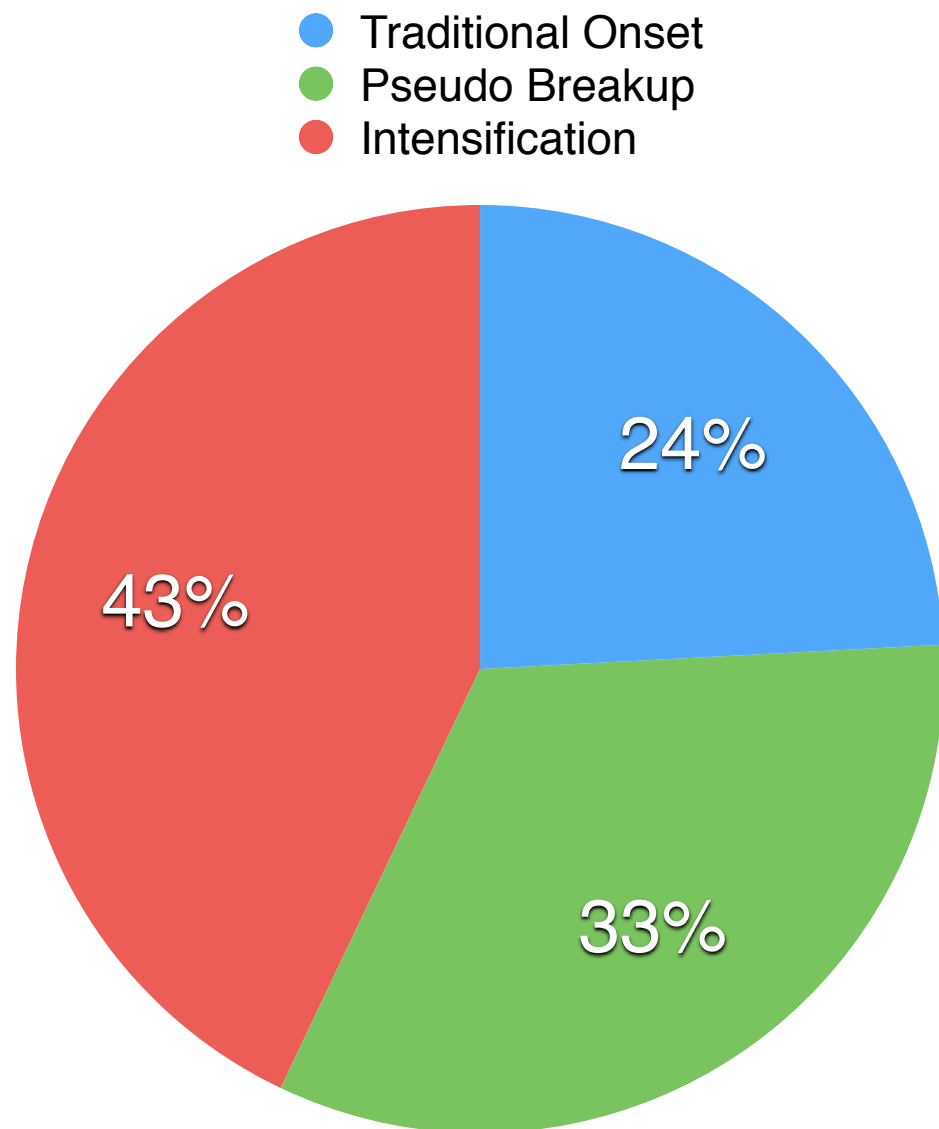
1. Pseudo breakups

2. Traditional onset

3. Intensifications

4. Harang onsets

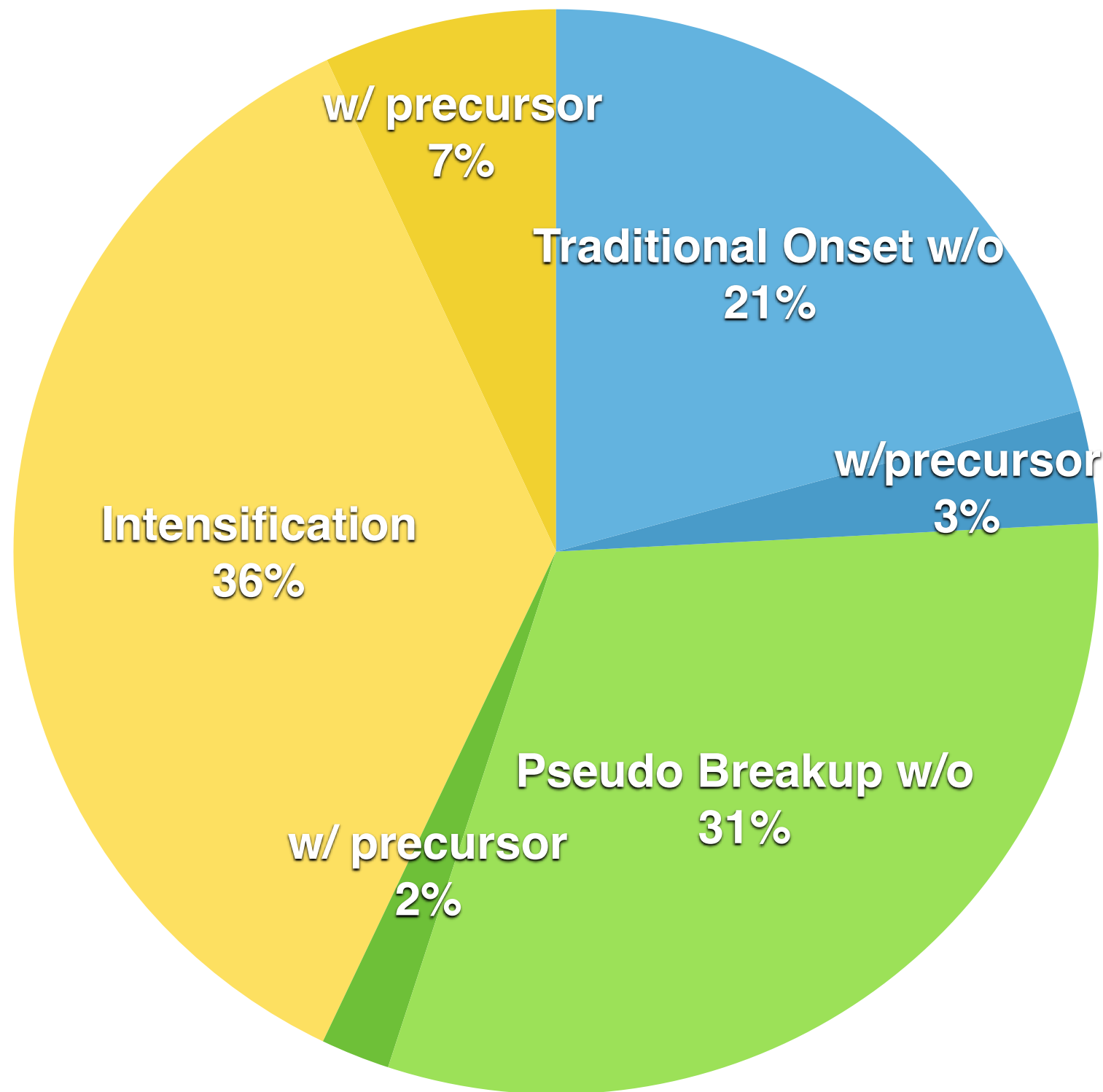
Magnetospheric configuration of Nishimura events (369 events)



All 3 events in *Nishimura* [2010] are intensifications;
third event associated with omega band/torch

Full assessment of arc/streamer contact

(369 events)



~12% show precursor of some type

Traditional onset streamers ***quite different*** from intensification streamers

*Excludes 'Harang onsets'

Comparison of identifications

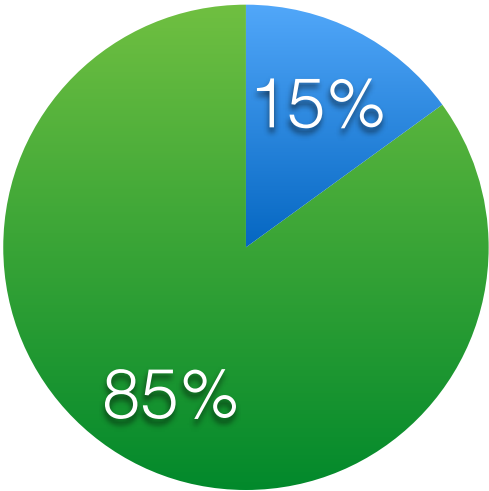
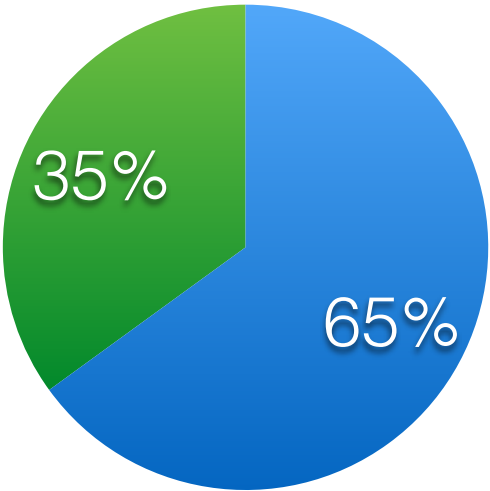
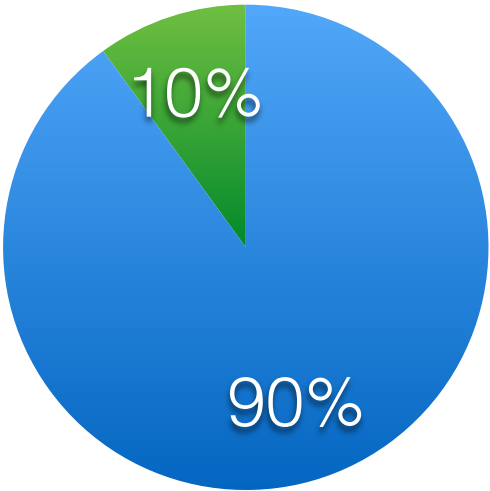
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Streamer	NM	NMK _*	NMK	NM	NM	NM	NM	N	N	N	N	NK	N	N	M					M
Arc								M	M	M					N	NM	N	N		
Neither	K			K	K	K	K	K	K	K	MK	M	MK	MK	K	K	MK	MK	NMK	NK
Type	I	I	I	I	-	I	I	S	P	I	I	I	I	I	I	I	I	I	P	I

Nishimura

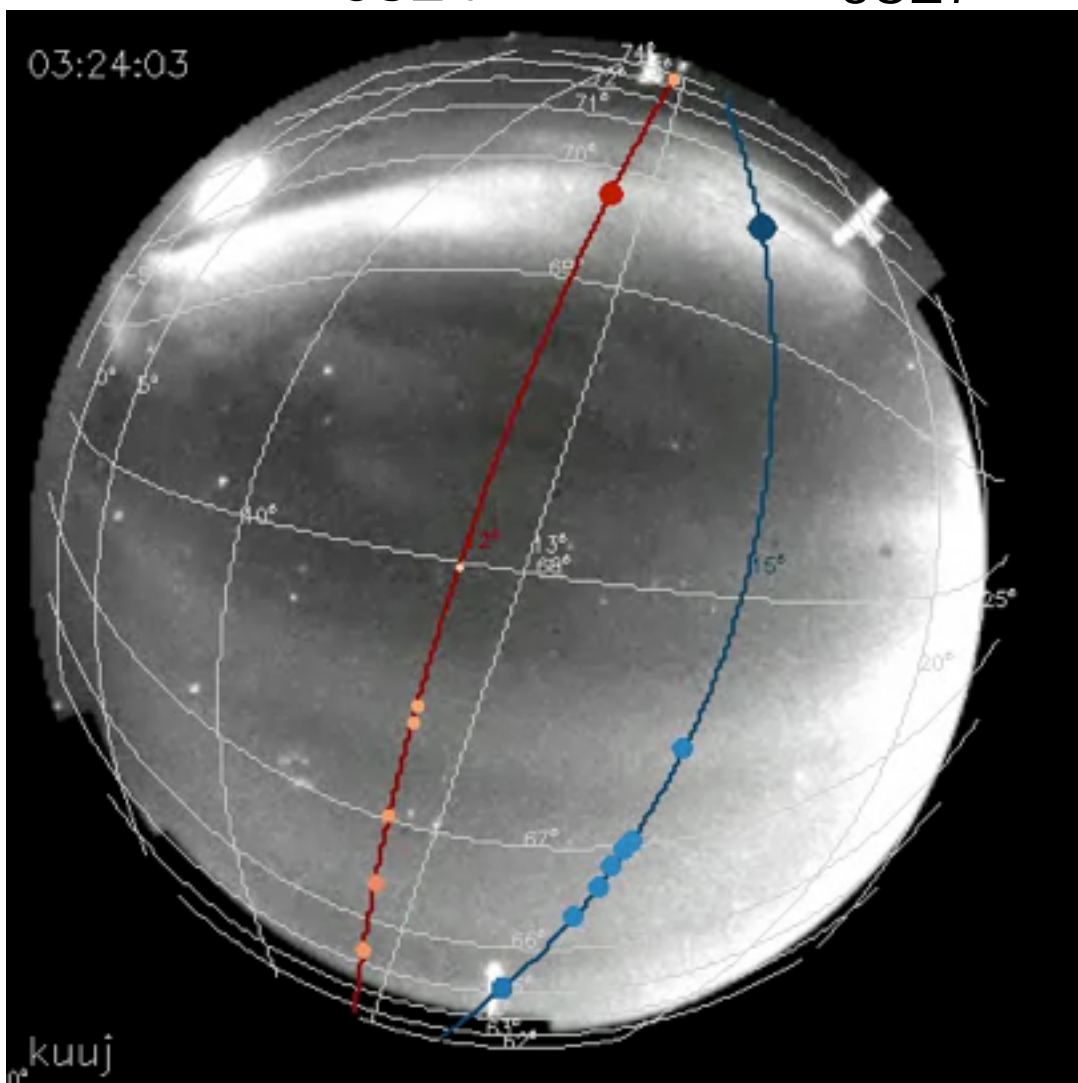
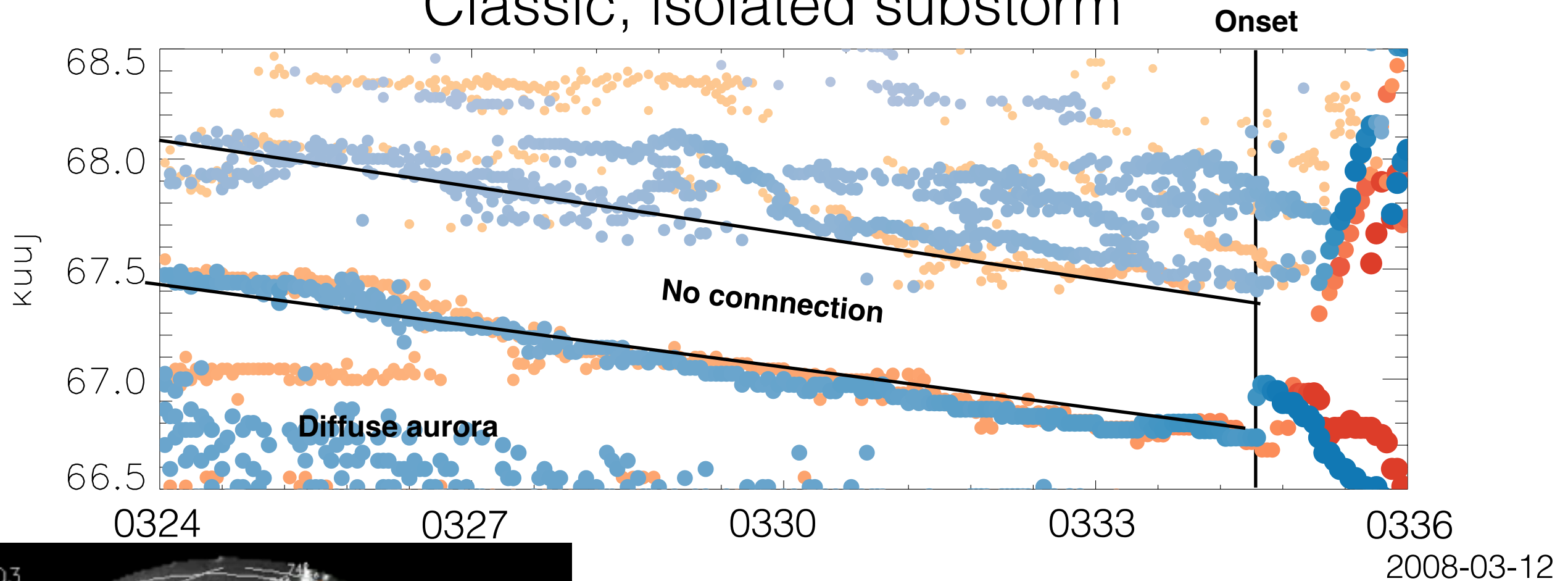
Mende

Kepko

- Streamer/arc
- No precursor



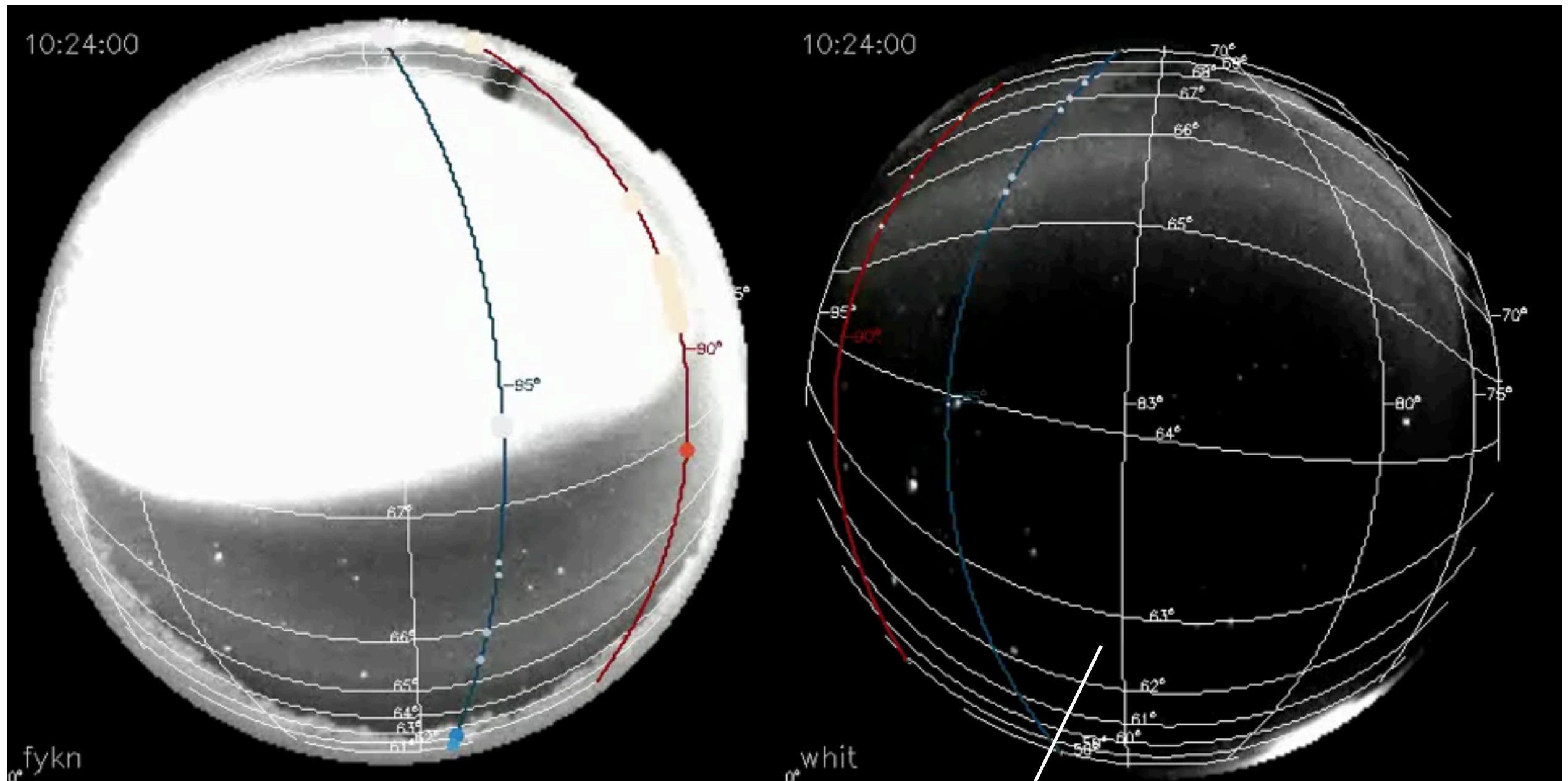
Classic, isolated substorm



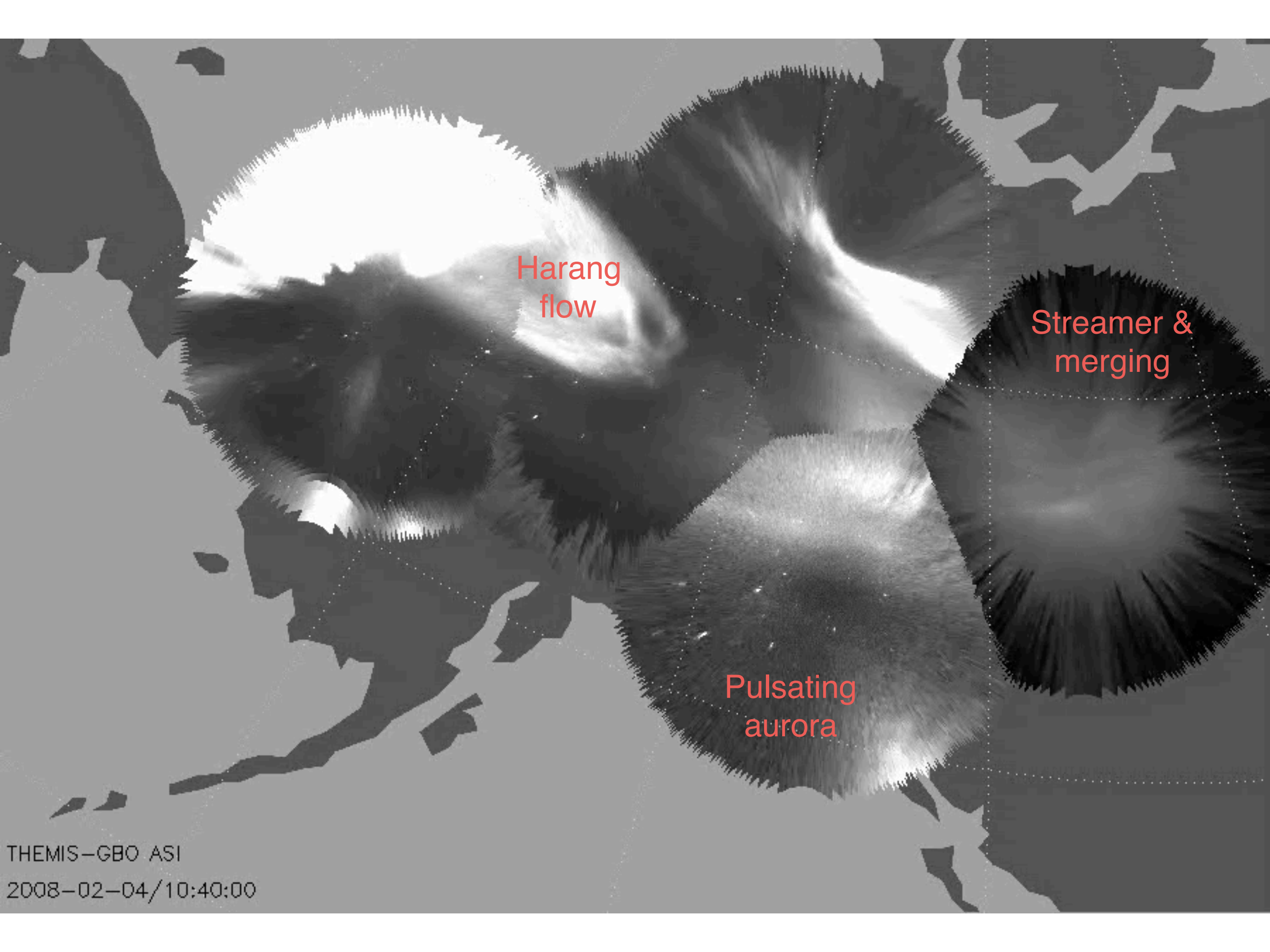
Two equatorward drifting
growth phase arcs. $\sim 1^\circ$
separation. Clouds moving SW

All positive associations are
questionable

Harang Onsets



Strong Harang flow, pulsating aurora, rigid equatorward boundary (65.5°), no growth phase signature, no clear streamer contact

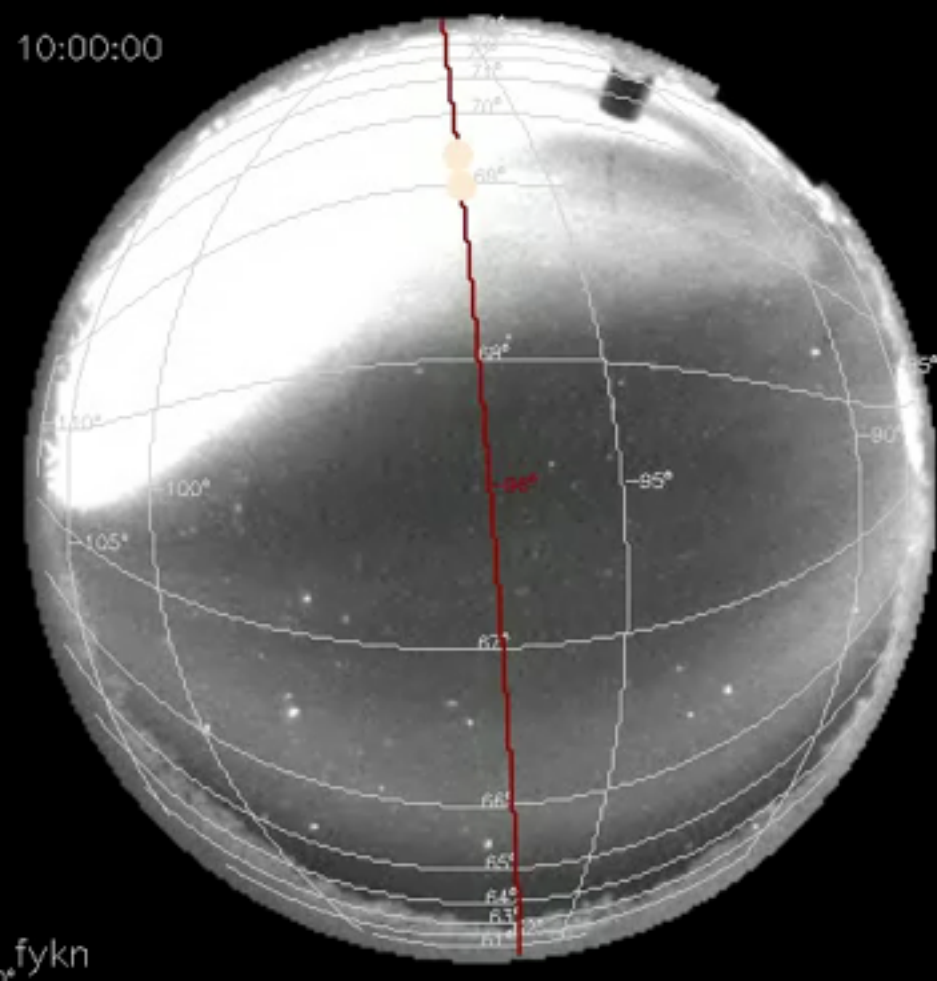


Harang
flow

Streamer &
merging

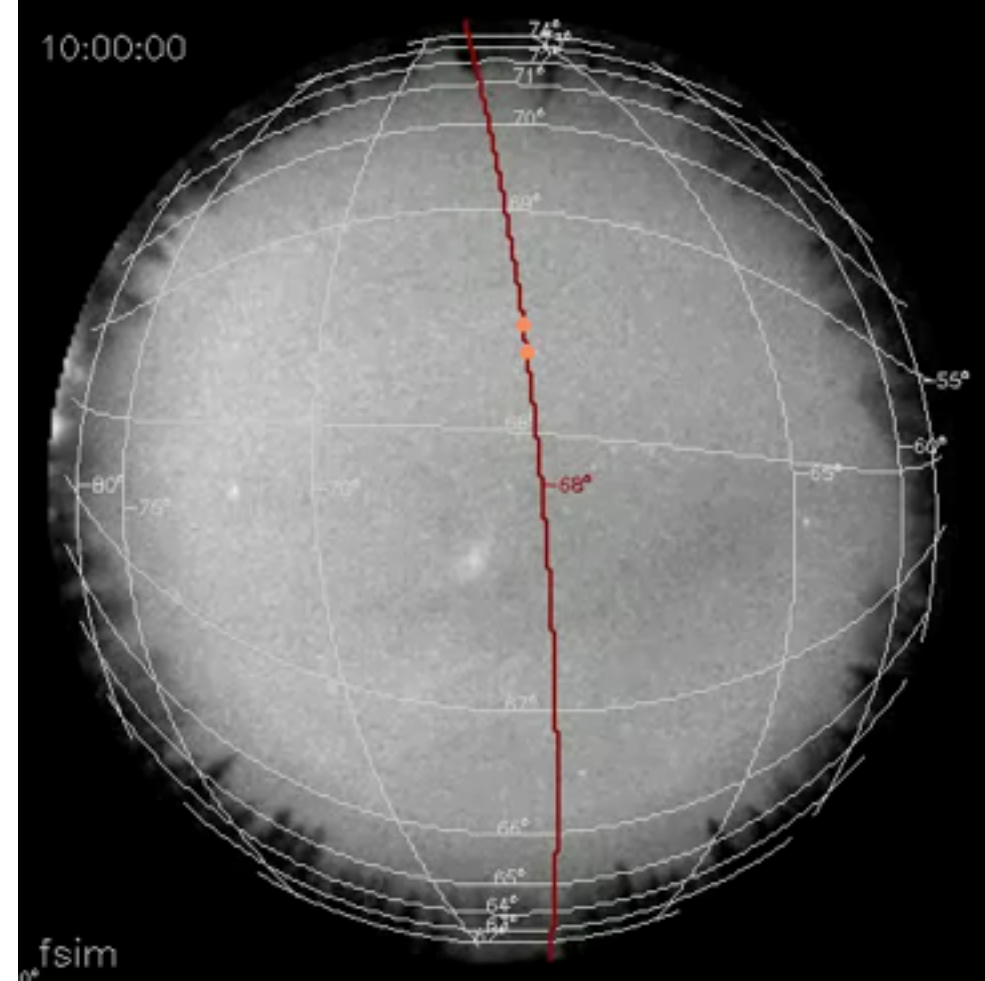
Pulsating
aurora

THEMIS-GB0 ASI
2008-02-04/10:40:00

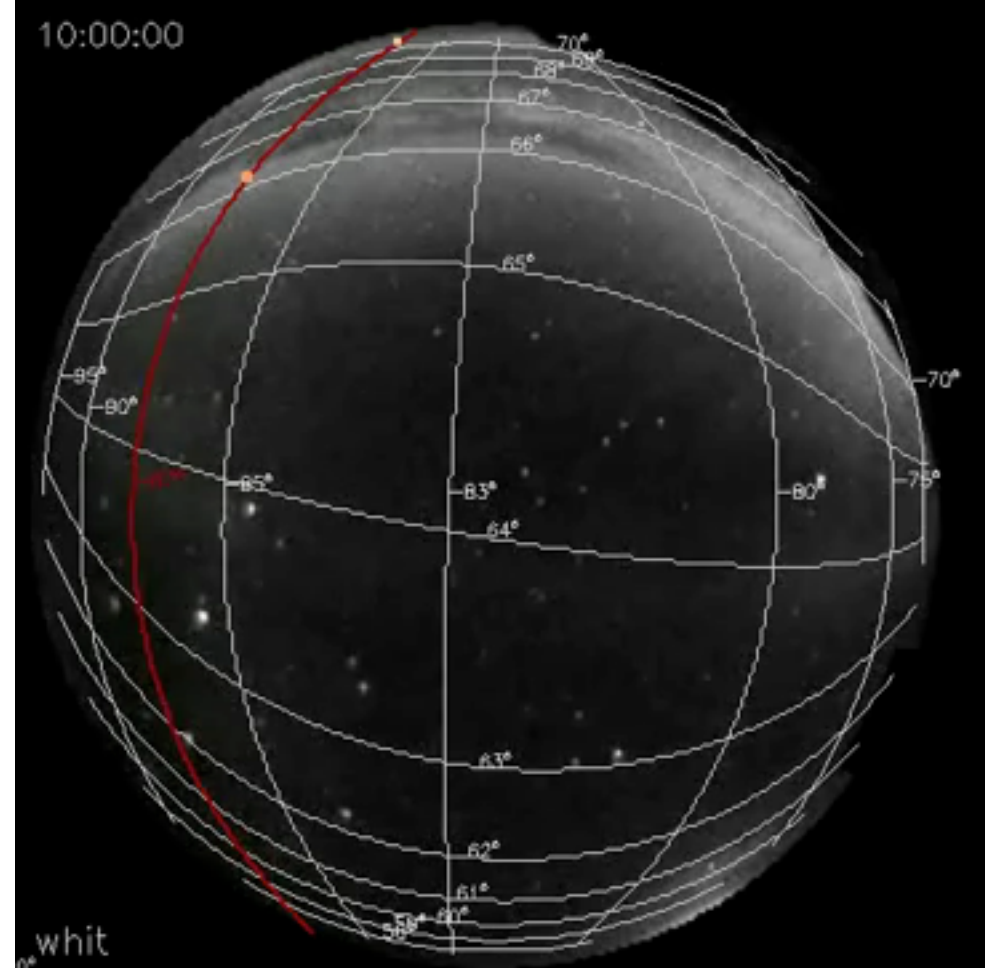


onset 1048

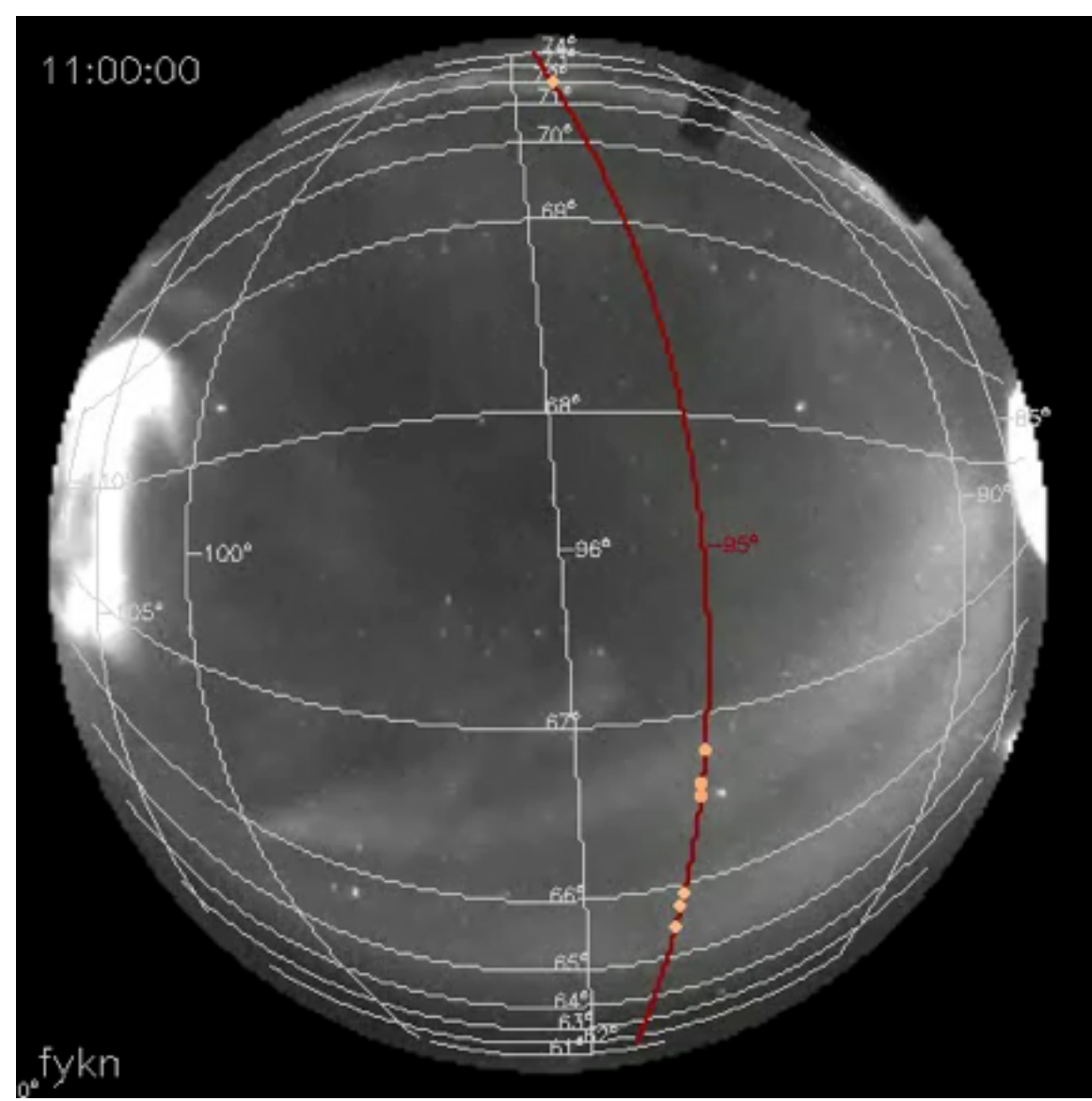
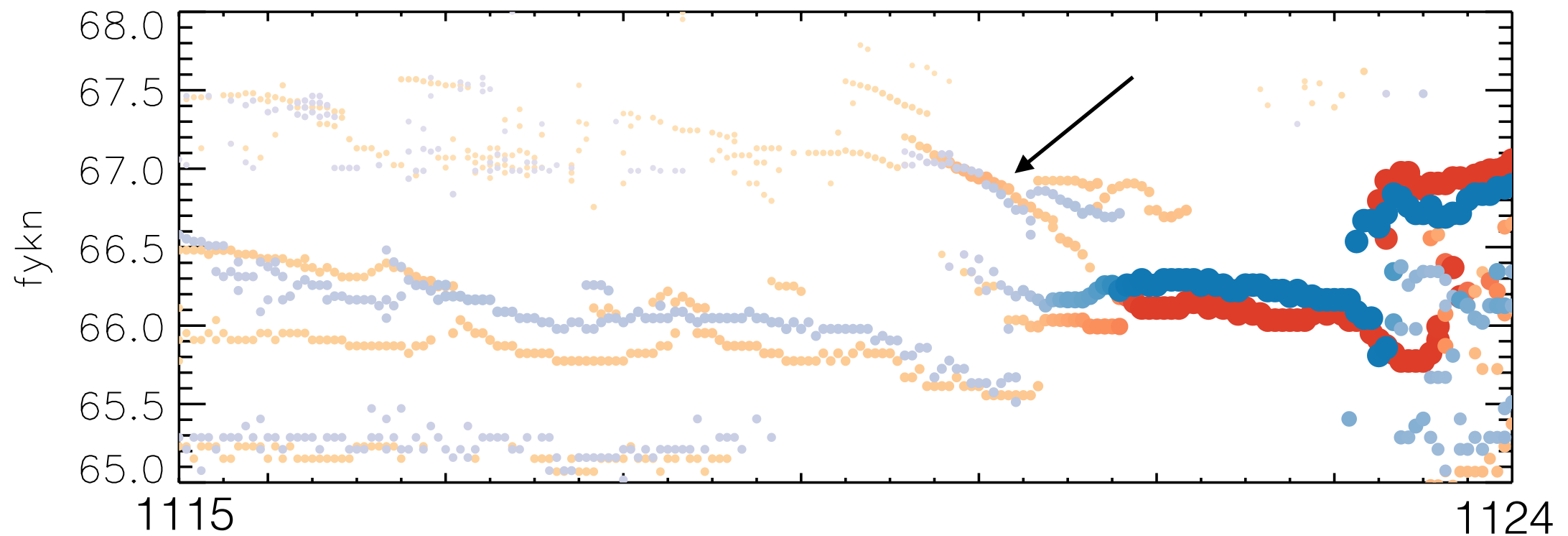
Slides across



streamer near
-68°, 1042

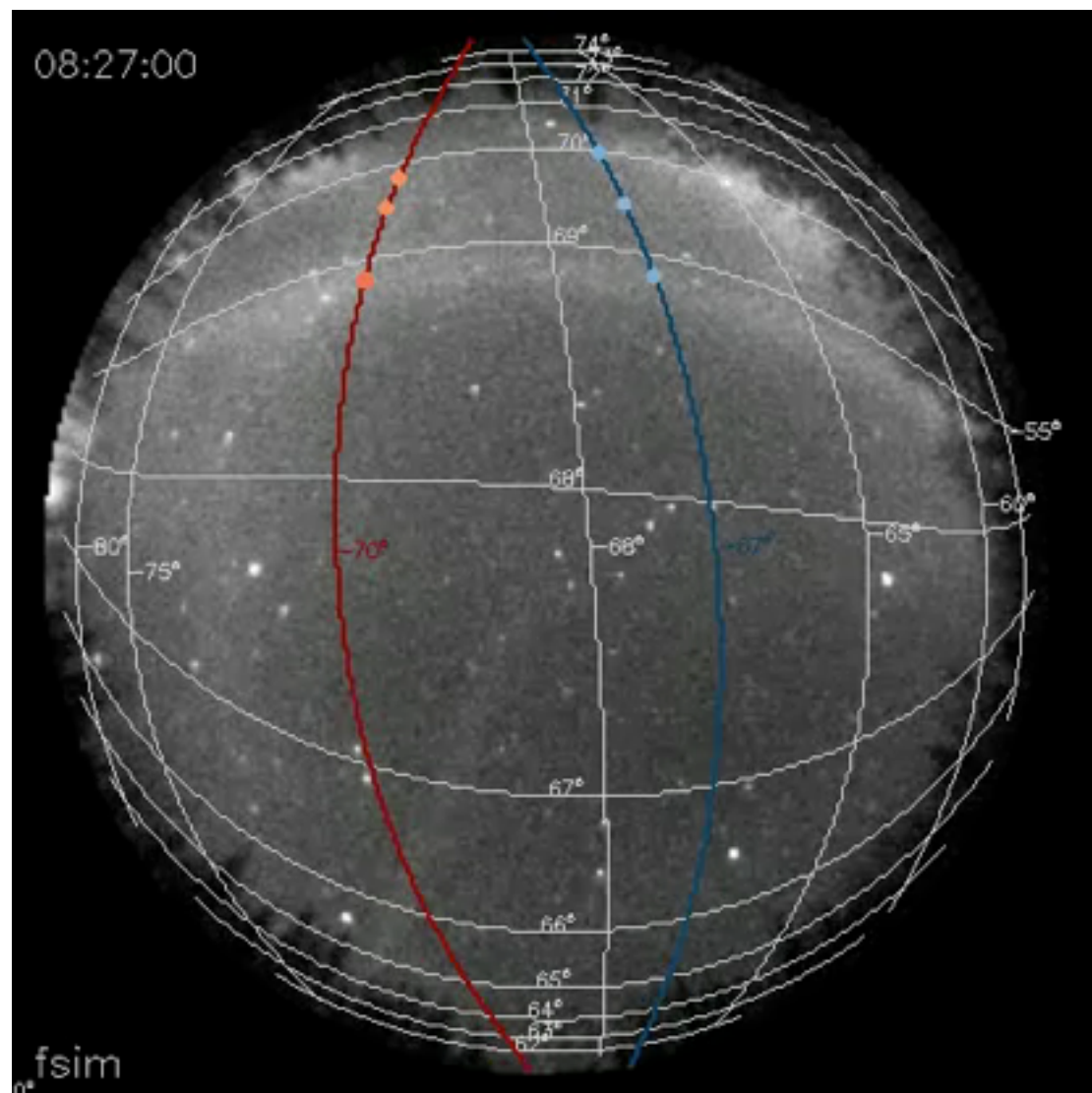
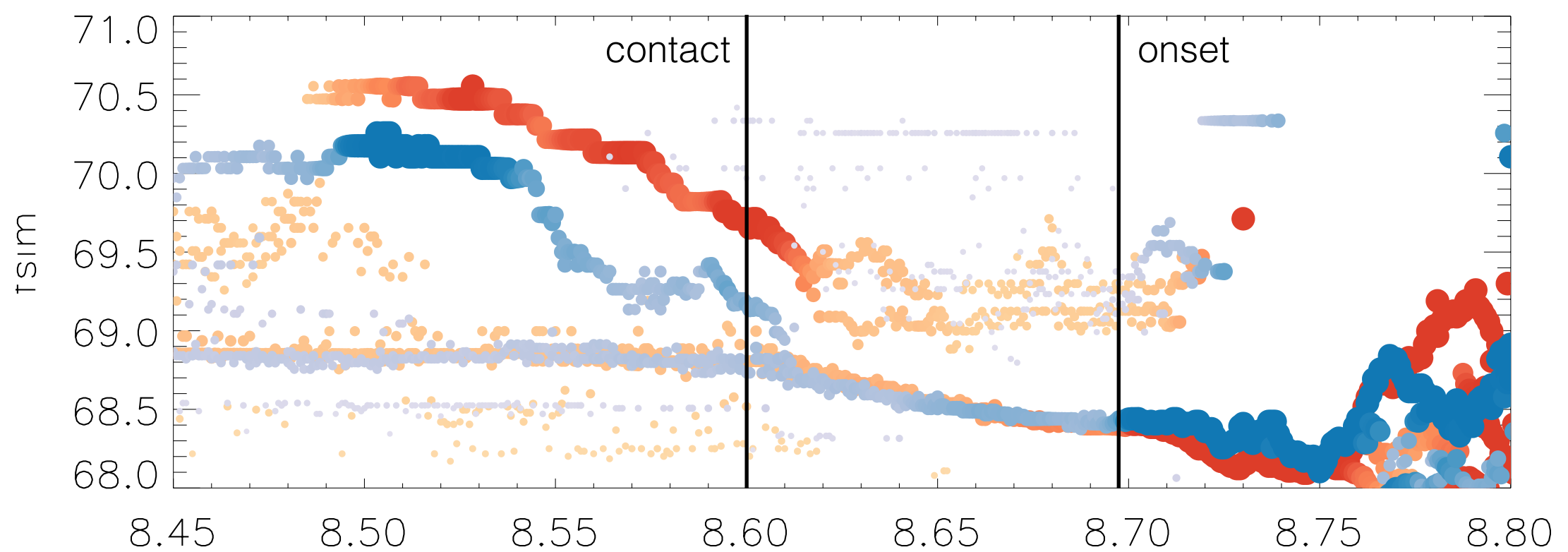


Intensification with streamer contact



Typical of the positive intensification examples.

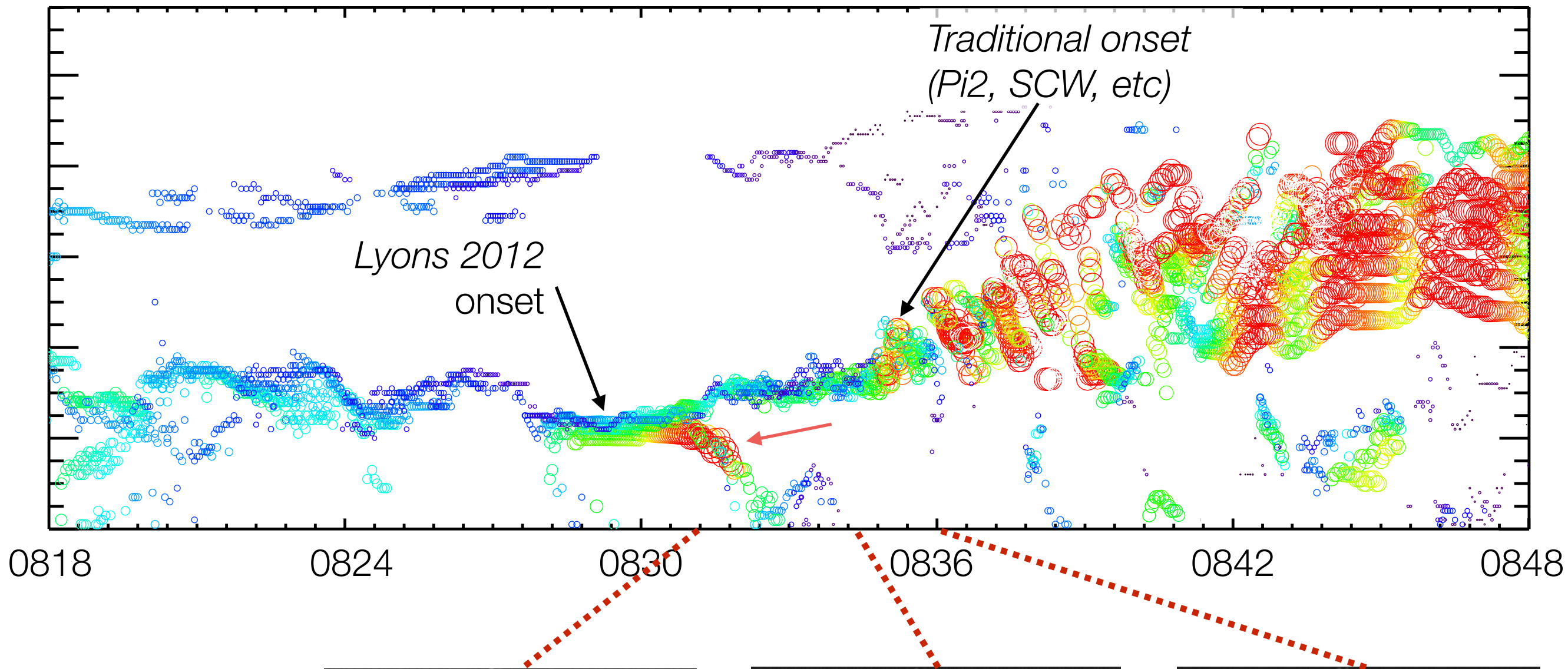
How does that 'streamer' relate to a flow? Is it coming from O/C boundary?



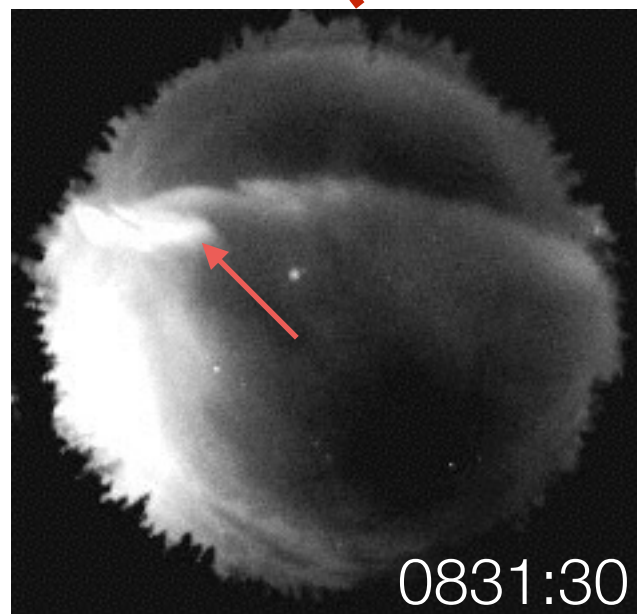
Pre-onset arc brightening

Class of events where
“streamer” appears to make
contact with growth phase
arc.

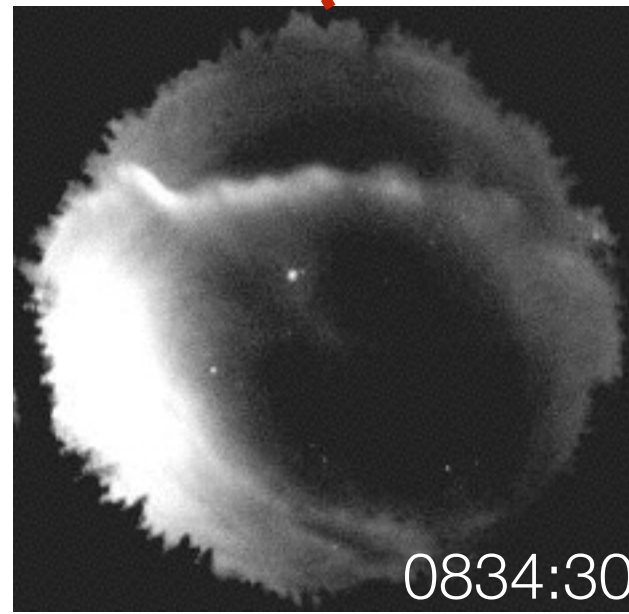
Many questions....



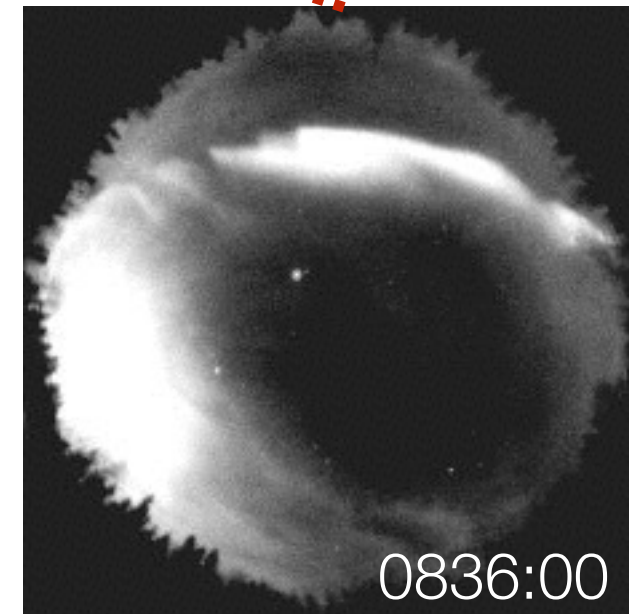
Jan 27, 2007
(Lyons et al., 2012)



*Growth phase arc
brightening and ripple.*

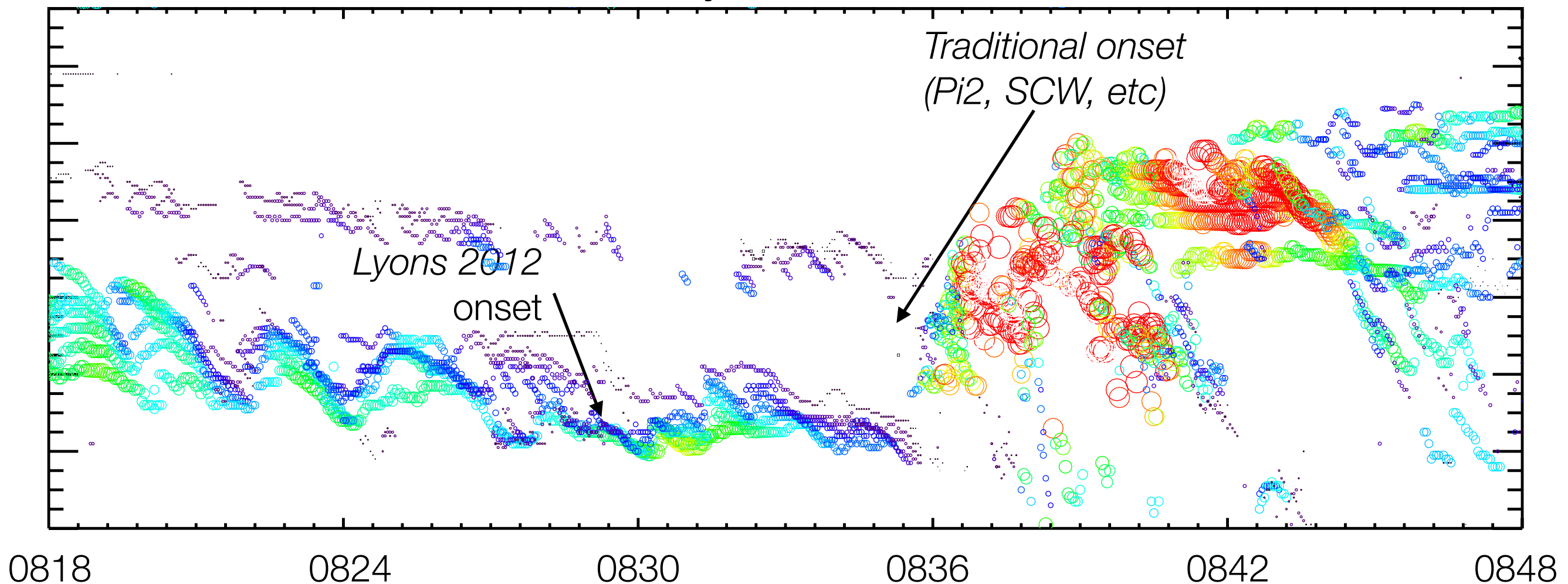


Little progress



Expansion, finally

Why it matters:



We ascribe significance to (even a little) arc brightening
But we do not know what sustains the growth phase arc.

When it brightens (or changes structure)*, is it because:

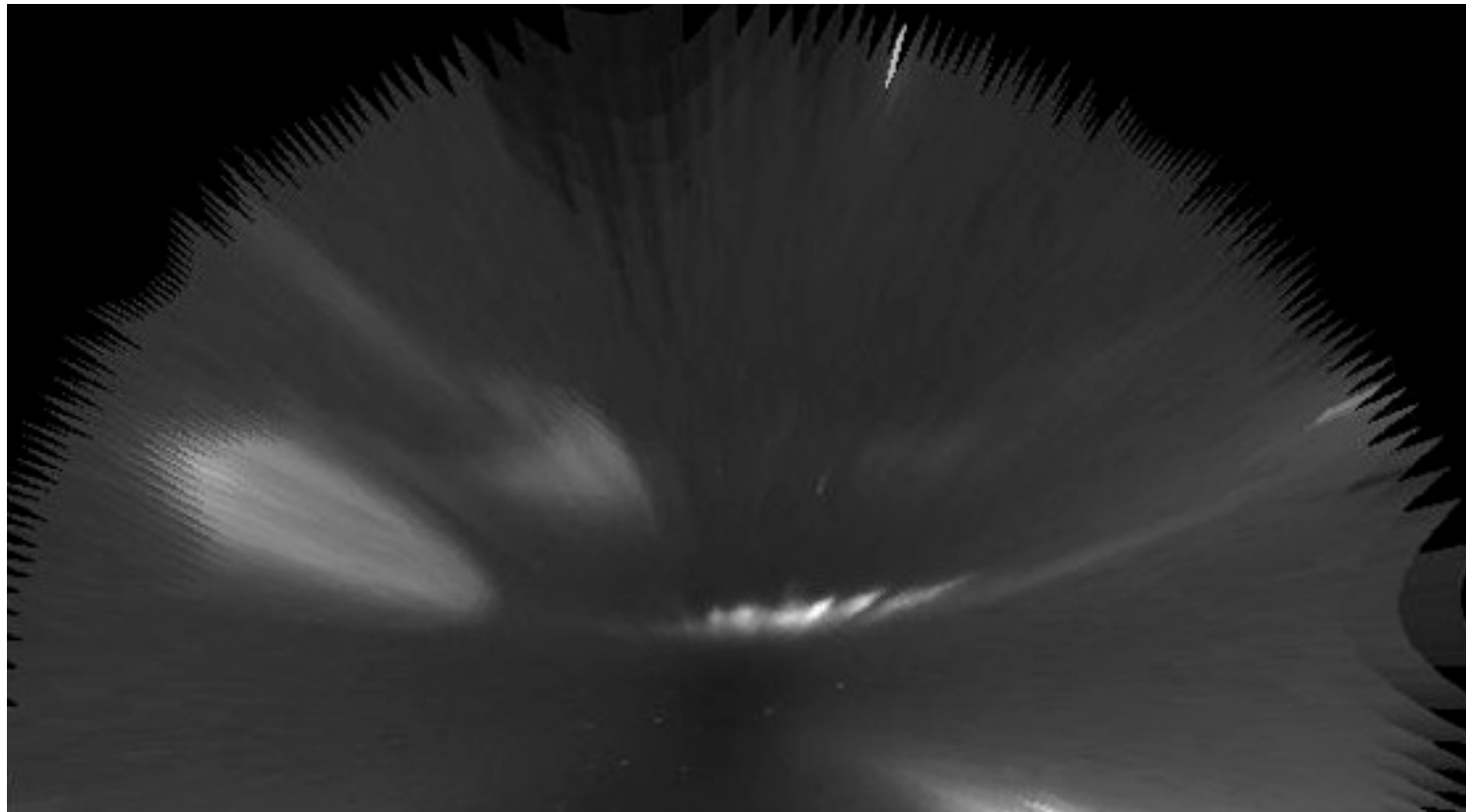
1. The underlying *growth phase arc* process intensified or changed?
or
2. Unloading has begun and the magnetosphere is changing topology or energy state.

Those are very different things.

*With the caveat: It might be a new arc entirely

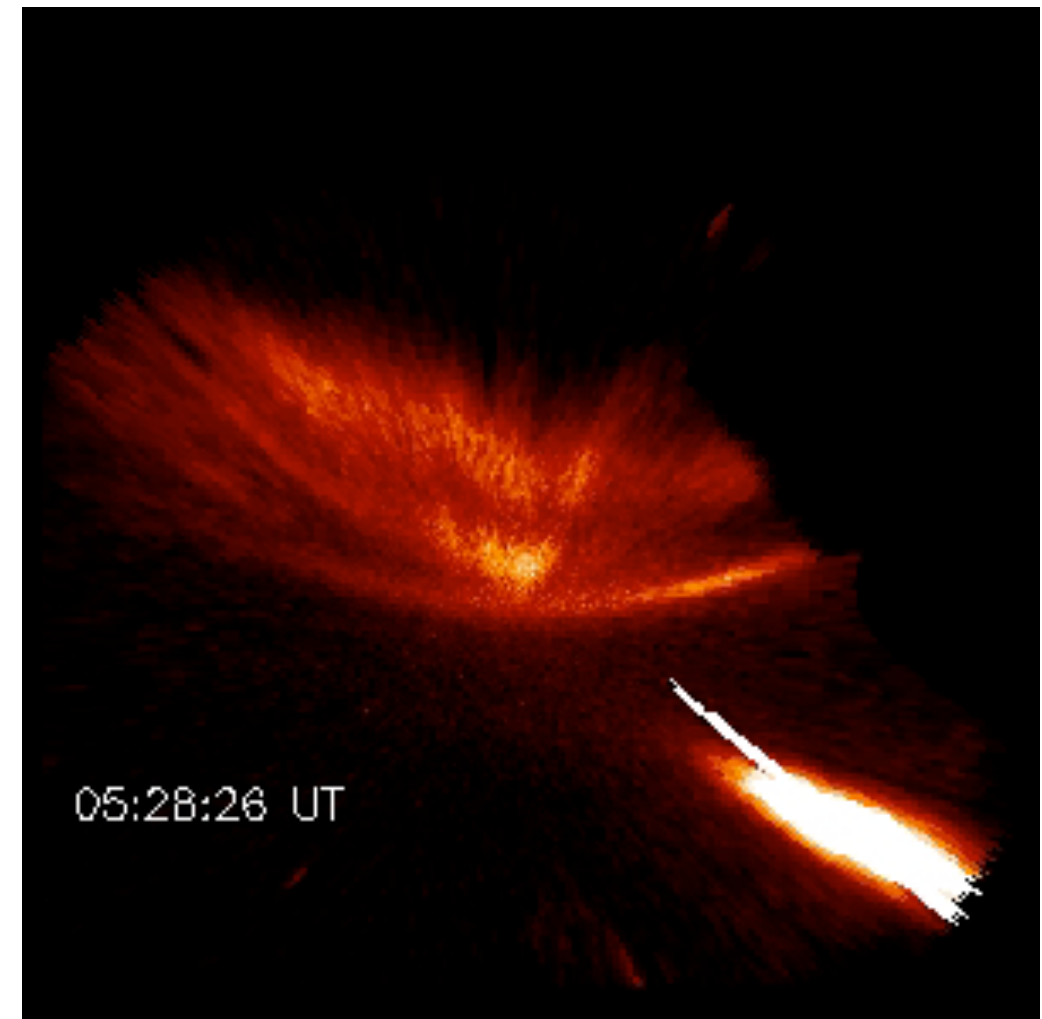
The value of 6300

White light auroral onset



White light shows no pre-onset feature, and shows beading - ballooning!

6300 onset



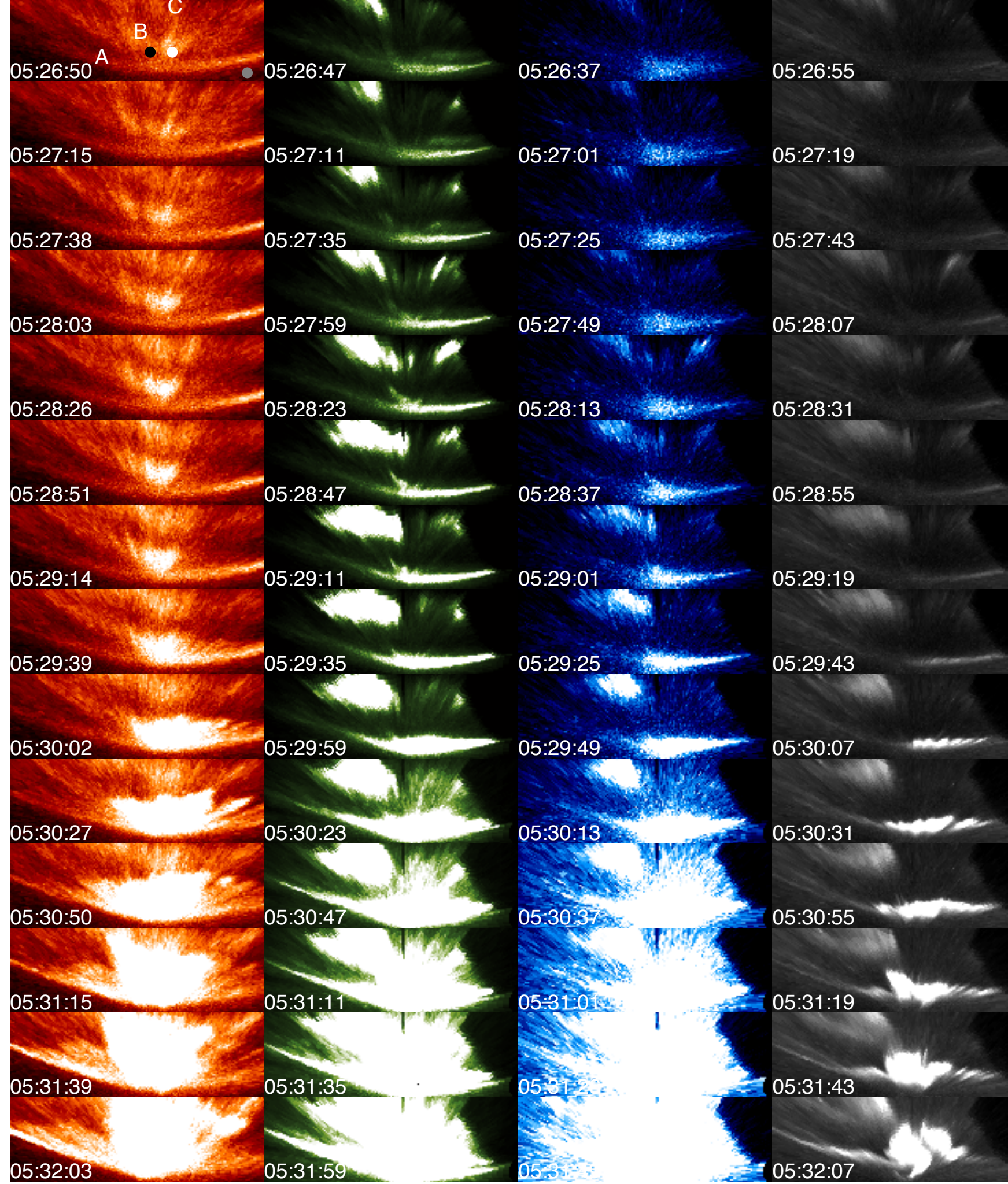
But redline shows the flow signature

Quick Review

0523:15 - 6300 activity
0526:47 - 5577 arc forms
0530:07 - VWL Beads
0530:31 - Poleward Exp

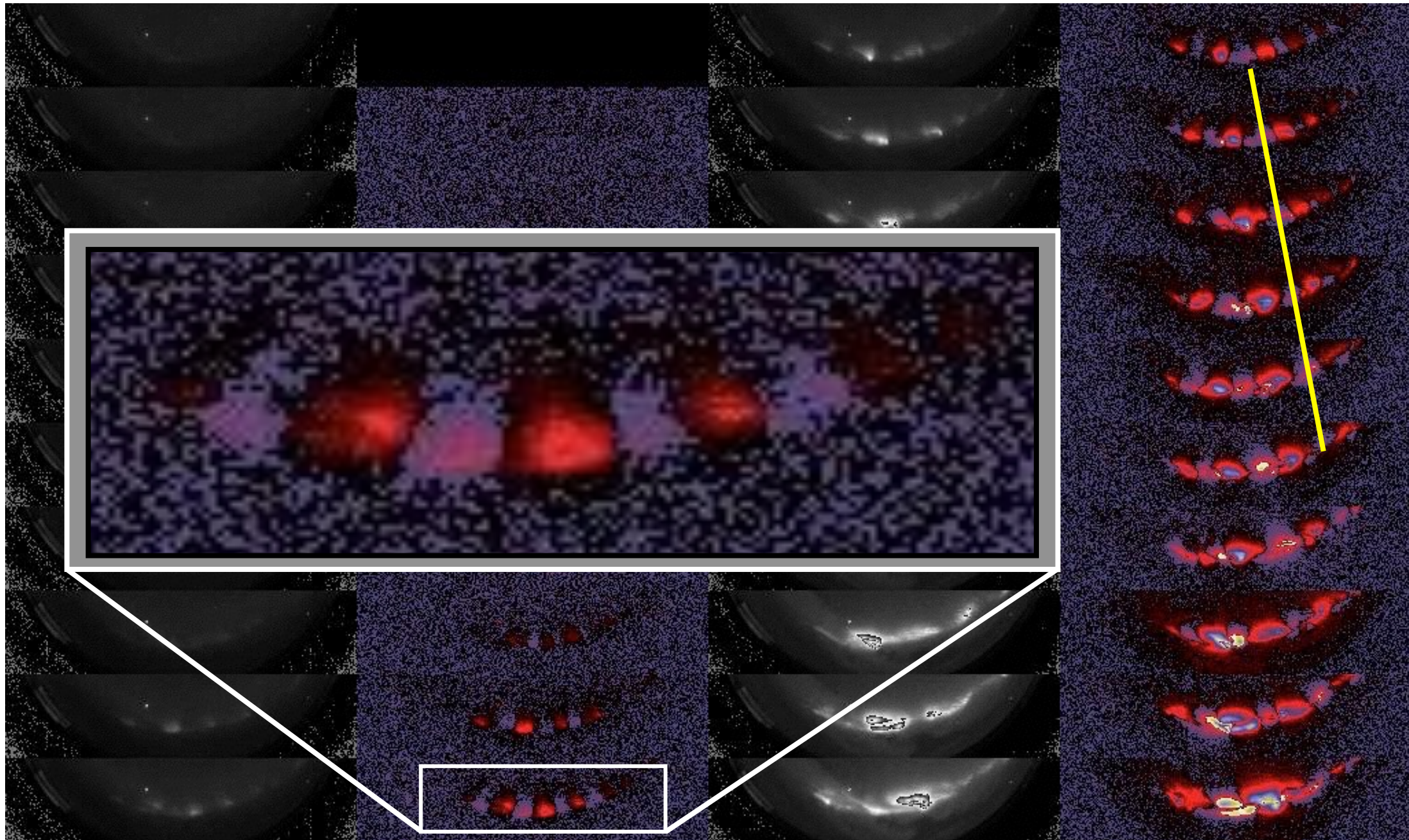
We observe a pre-onset, equatorward moving diffuse auroral patch

Kepko et al., 2009 GRL



Optical Onset

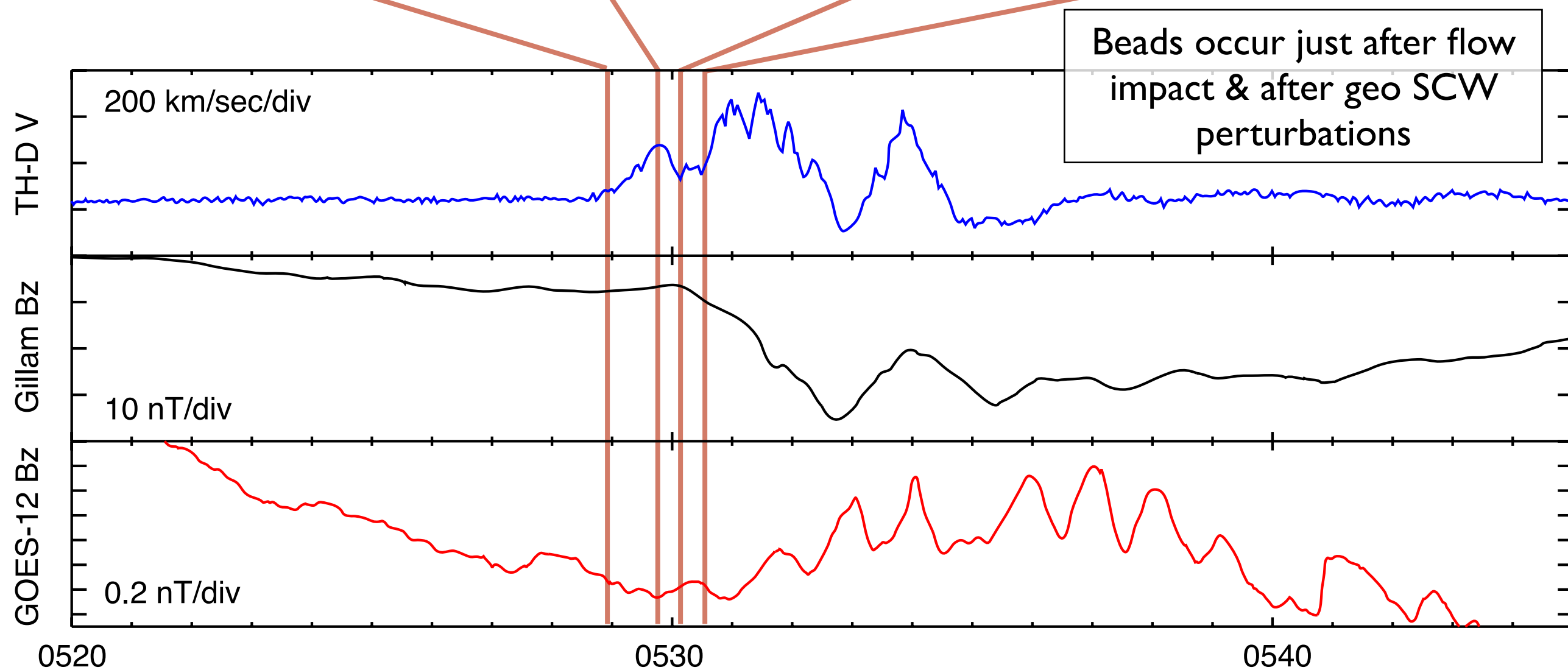
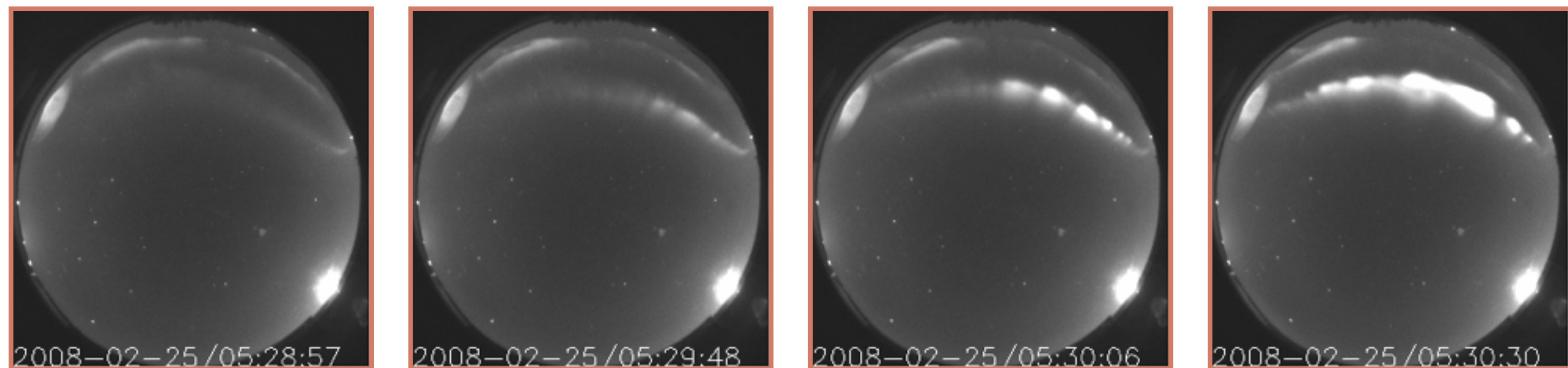
Why do I (Eric) think it is traditional Inside-Out?



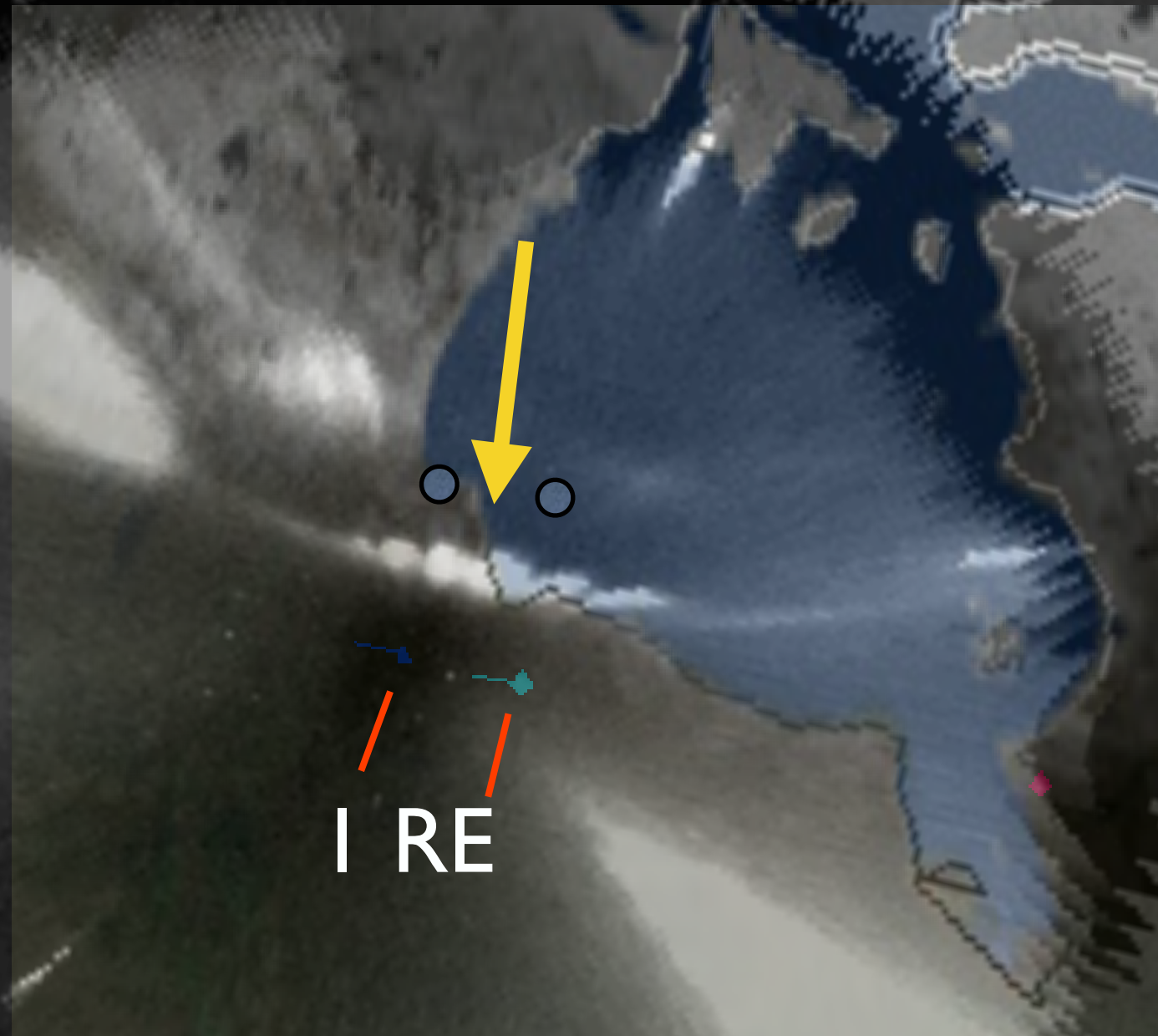
*Partial images (and difference frames) from THEMIS ASI at Athabasca
The talk I initially conceived would have been entirely around this point.*



Growth → Rays → Beads → Expansion

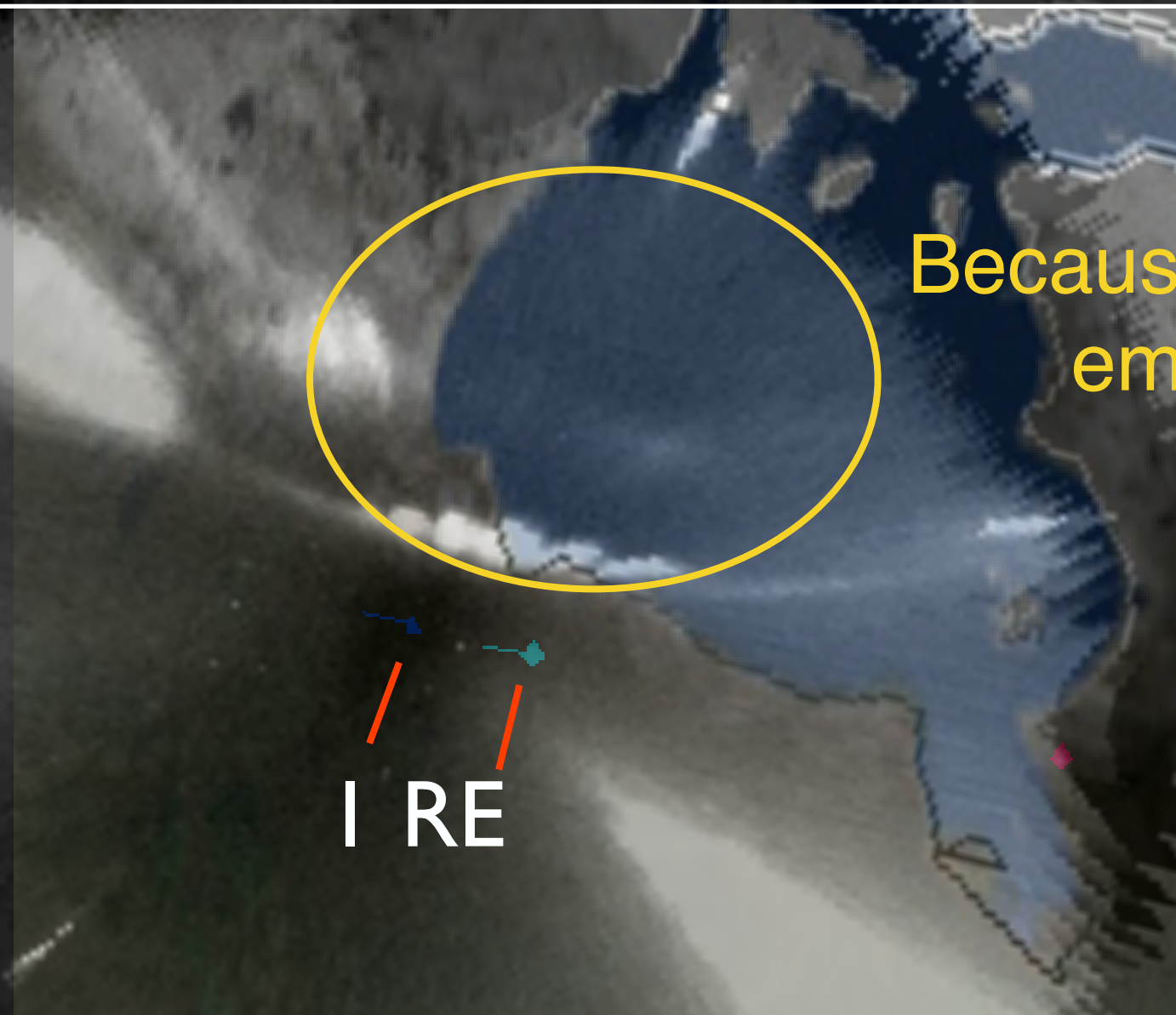


Flow channel observed before
beading



Beading a consequence of flow
a “detail”

If we did not have THEMIS in situ...
Or the red line data...
This would be a ballooning triggered onset



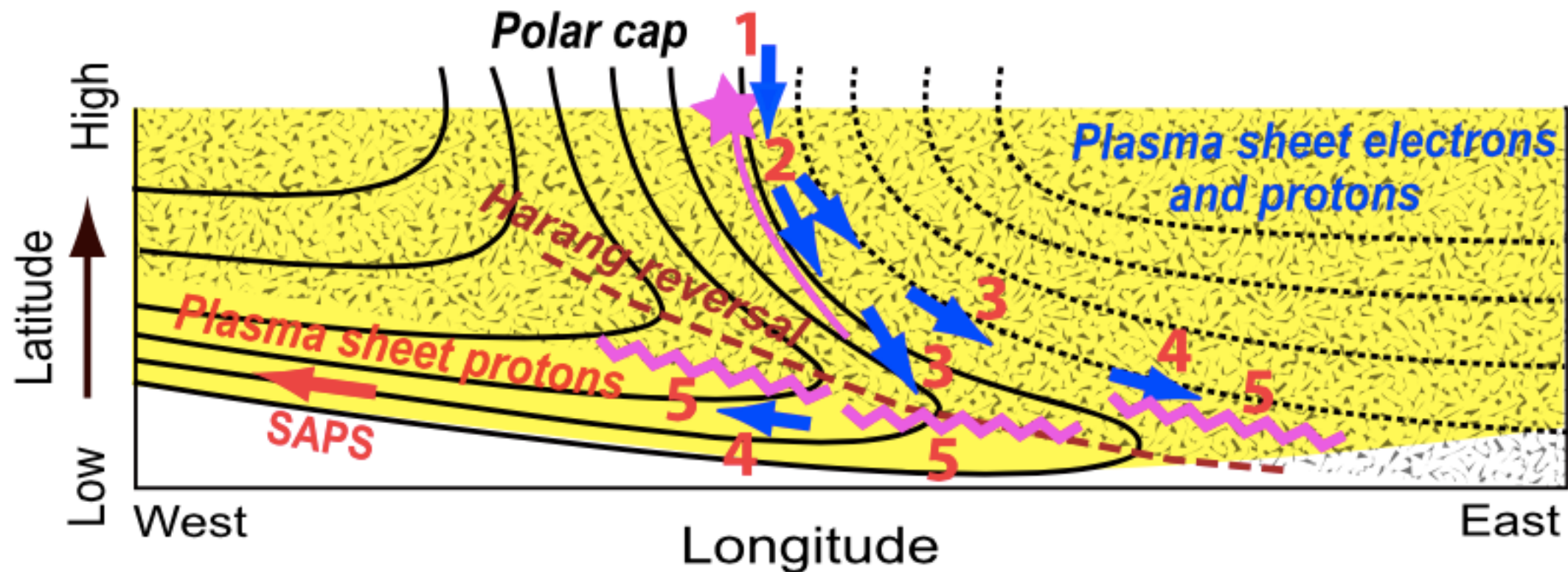
Conclusions

1. Nishimura event list is a rich dataset, with a diverse set of events. It is not a substorm dataset.
 - Important to separate event types
 2. I found % of activity with pre-onset streamers/arcs $\ll 95\%$
 - And ΔT and ΔLT are near zero (except Harang)
 - More consistent with direct flow-driven scenario
 3. Difficult to find substorm pre-onset streamer. Precursor, if there, is diffuse, follows NENL predictions.
 4. Harang onsets are a real thing, and follow the NLS scenario
 5. Beading likely a consequence of flow braking.
-
6. We don't know the magnetospheric drivers of auroral arcs
 - Not even the growth phase arc
 7. Community lacks criteria/tools for reproducible results

The configuration of the magnetosphere differs between event types

Substorm onset represents a change in magnetospheric configuration

During intensifications, magnetospheric is processing, rather than storing, solar wind energy



What we learn about streamers during active conditions does not necessarily apply to initial stages of a substorm, unless you see the same features (we don't)